Australian Government
Land & Water Australia

CSIRO

Managing genetic diversity in remnant vegetation

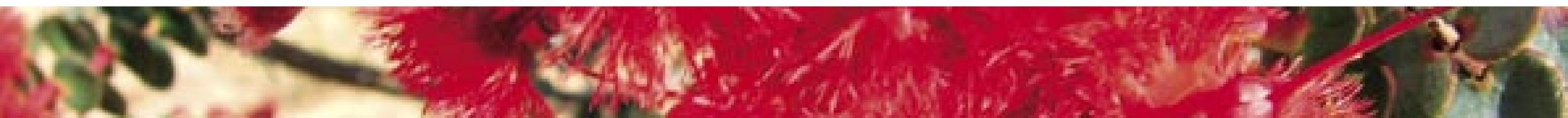
By Linda Broadhurst

TECHNICAL NOTE **01/2007**

IMPLICATIONS FOR LOCAL PROVENANCE SEED SELECTION AND LANDSCAPE RESTORATION

Summary of key points

- Fragmentation of Australia's native vegetation is threatening the long term persistence of remnant plant populations even among the more abundant or common plant species.
- Research has assessed the importance of several genetic and demographic factors for maintaining healthy remnant populations.
- Population size and isolation play important roles in determining the persistence of remnant vegetation. Small populations (less than 100 – 200 reproductive plants) are highly susceptible to declining seed production, loss of genetic diversity, increased inbreeding leading to poor seedling vigour and increased hybridisation.
- Results from this study have led to a number of recommendations on how to manage remnant populations including maintaining large reproductive populations above 100-200 individuals, minimising the distance between populations, and managing populations on the landscape level rather than as independent groups of plants.
- Seed sourced from remnant populations suffering poor genetic health will probably produce poor revegetation results.
- Improving and maintaining the health of remnant vegetation will ensure their long term persistence and provide more high quality seed for revegetation projects.



Background - Remnant vegetation in the Australian landscape

Australia's vegetation has become fragmented following decades of land clearing, and in many regions only small pockets of isolated plant populations remain. These remnants range from a few plants to many hundreds and their ecological and genetic health is highly variable and depends on many factors. The negative impacts of broadscale land clearing on the Australian environment have been well documented and much is now being done to repair the damage. One way of ensuring that further degradation does not occur is to carefully manage the remnants that we have left. This is particularly important because remnant vegetation plays an integral role in many landscapes such as providing habitat and resources for our unique flora and fauna and essential services for maintaining ecosystem health. In some cases these remnants are also the only representatives left of some vegetation types and are likely to disappear without careful management. In addition, remnant vegetation is now expected to provide the ever increasing volumes of seed required for restoration. As such, the vegetation remaining in fragmented regions of Australia represents a significant amount of 'environmental capital' that we need to protect and manage for generations to come.

To successfully manage remnant vegetation we need to understand the genetic and demographic effects that fragmentation is having on the long term future of plant populations. In an effort to provide some management guidance, researchers from CSIRO Plant Industry and the Western Australian Department of Environment and Conservation assessed how population and landscape parameters are influencing the genetic and reproductive health of remnant vegetation, and whether these factors represent serious constraints for long term population persistence of our remaining plant populations.

Investigating remnant health

Using a multidisciplinary approach that integrated field-based demographic monitoring, experimental growth trials and genetic analysis the team assessed the viability of remnant populations of seven plant species in two contrasting ecosystems.

The ecosystems were the temperate grasslands and grassy woodlands of New South Wales and the Australian Capital Territory, and the kwongan shrublands of the Dongolocking region in Western Australia (Fig. 1). Both of these ecosystems have experienced severe habitat loss and disturbance over the last century and the extent and condition of the remaining vegetation is highly variable. These two ecosystems were chosen because of the contrasting fragmentation patterns and remnant vegetation structure.
In the temperate grassland-grassy woodland ecosystem, intact remnant vegetation is embedded in improved native pastures, while remnants in the kwongan are physically isolated by wheat and grazing land. By choosing these two different ecosystems, researchers could test whether species were responding to fragmentation in a similar way, irrespective of geographic location or vegetation type.

Figure 1 Map of Australia with both study regions indicated

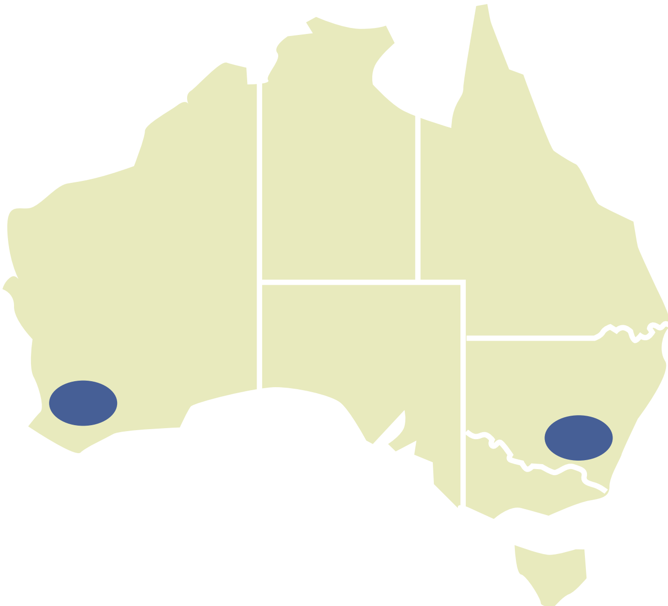


Figure 2 Variegated grassland-woodland ecosystem in New South Wales (photograph – Linda Broadhurst).

Species under investigation

Seven common plant species were targeted for investigation and were chosen to represent the different life-histories present in each of the ecosystems (Table 1). These differences included pollination syndromes (flower traits associated with different pollination strategies) and seed dispersal that are likely to be influenced by vegetation fragmentation. Common species were targeted for this study because as the most abundant plants in remnant vegetation, their loss is likely to impact on other species in many different ways. For example, these plants may provide habitat, protection and food for insects and animals but they may also provide shade for other smaller plants. While rare species are already showing negative effects associated with fragmentation, this project helped inform whether common species are responding in a similar manner.

Preparing plant samples for genetic markers to track levels of gene flow

Study populations were chosen for each species to represent the range of remnants present within each ecosystem. Each species was assessed for:

- Population size,
- Level of isolation,
- Floral species diversity, and
- Remnant condition.

Plants were tagged at each site and reproduction was monitored by assessing flowering, pollinator visitation, pollination, fruit maturation and seed set. Seed were collected to determine the levels of genetic diversity and inbreeding, and growth trials were conducted to determine whether inbreeding was influencing germination and seedling growth.

Calothamnus quadrifidus in flower

Gene flow between populations in *Eucalyptus wandoo* and *Calothamnus quadrifidus* were also determined to provide information about pollen flow in fragmented landscapes and the effects that this might have on population viability.

The research team also investigated relationships between remnant characteristics such as population size and isolation, and the genetic and demographic responses including genetic variation and inbreeding.

TABLE 1 Target species and life-history characteristics

Ecosystem	Taxa	Life form	Pollination	Dispersal	Longevity
S.E. AUSTRALIA	*Eucalyptus aggregata*	Tree	Insect	Wind/gravity	› 100y
	Acacia dealbata	Tree	Insect	Bird/gravity	›20y
	Acacia acinacea	Shrub	Insect	Bird/gravity	›20y
	Swainsona sericea	Herb	Insect	Insect/gravity	›5y
WESTERN AUSTRALIA	*Eucalyptus wandoo*	Tree	Bird/insect	Wind/gravity	›100y
	Calothamnus quadrifidus	Shrub	Bird/mammal	Gravity	›40y
	Eremaea pauciflora	Shrub	Insect	Gravity	›40y

Key findings

The responses of remnant plant populations in this study have identified a number of key factors influencing the conservation and management of remnant vegetation.

1 Common species are experiencing negative effects associated with ecosystem fragmentation

Common native plant species are experiencing similar negative genetic and demographic effects associated with habitat fragmentation to those observed in less abundant plant species, irrespective of geographic location. These negative effects are influencing both the viability of remnant populations, and their value as seed sources for revegetation and restoration projects. This supports previous data from rare plants and confirms landscape fragmentation as a major threatening process for Australian plant ecosystems.

2 A species' reproductive biology influences it's response to fragmentation

The multi-disciplinary approach of this study has identified that reproductive biology played a major role in the response of species to fragmentation. For species that do not routinely self-pollinate such as many acacias negative effects were associated with poor reproduction – fewer compatible mates in smaller populations resulted in declining seed production. Reproduction in self-pollinating species was not affected in small populations, but the germination and growth of seedlings from these populations was poorer. In mixed-mating species such as eucalypts, increased hybridisation appears to be related to changes in the relative abundance of each species and hybrid progeny can suffer from poor fitness.

3 Remnant viability thresholds are in the 100s of plants

Population size is critical to the persistence of remnant populations. Results indicate that irrespective of which species was assessed, major negative effects were encountered when population size fell below 100 – 200 reproductive plants.

4 Hybridisation is an important threat to remnant health

Increased hybridisation has been identified as a major threat to the genetic integrity of plant species in small remnants. This is likely to be a widespread issue for several important Australian plant groups, such as eucalypts that can readily hybridise.

5 Gene flow between populations is critical

Results from *Calothamnus quadrifidus* and *Eucalyptus wandoo* (Fig. 3) showed that small populations can be genetically rescued by the movement of pollen from other remnants in the landscape over a scale of several kilometres. This connectivity between populations indicates the importance of managing landscapes rather than individual populations.

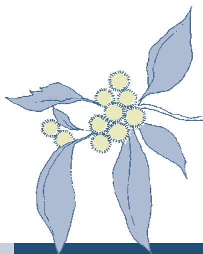
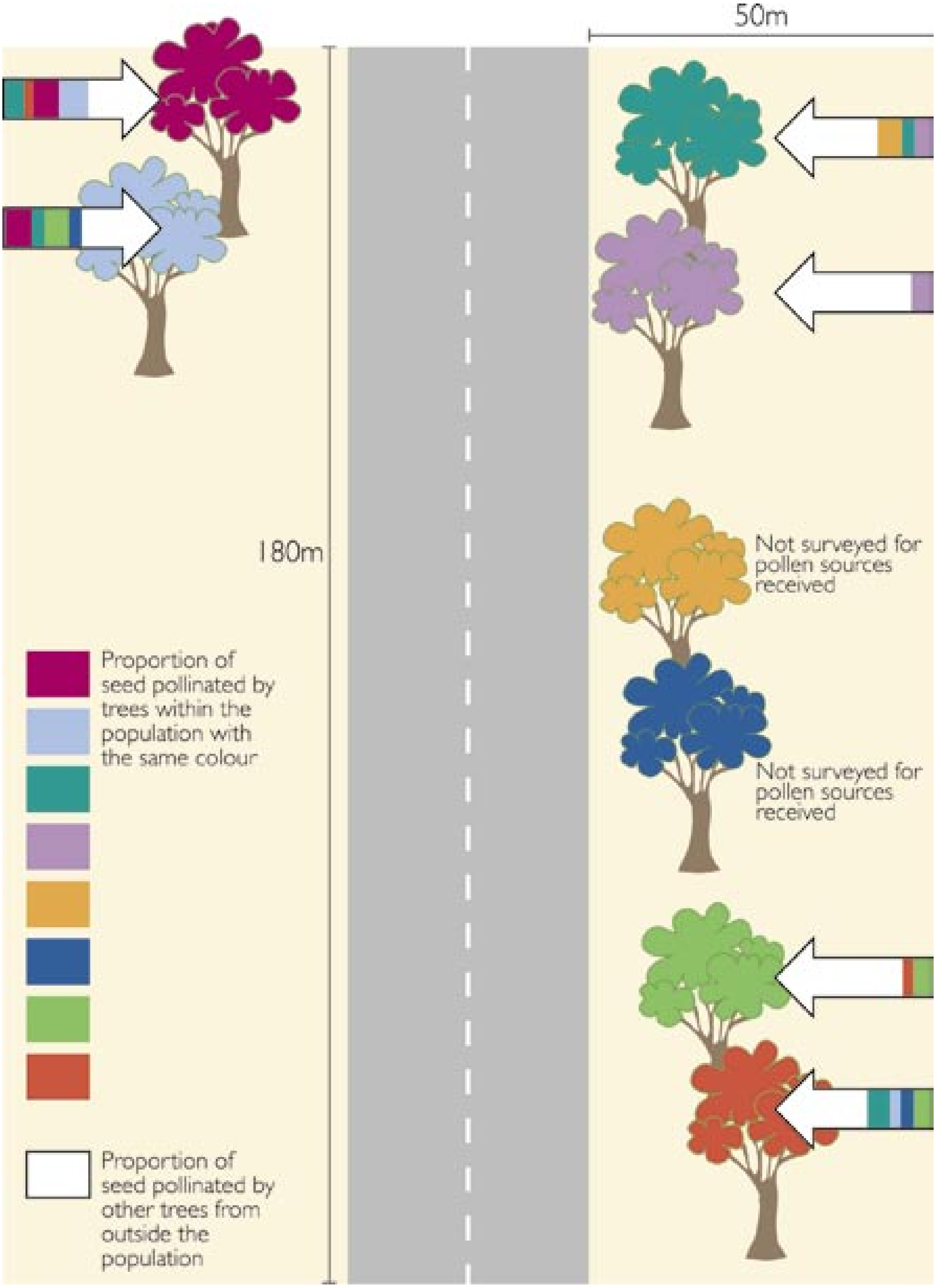


Figure 3 Paternity analysis for *Eucalyptus wandoo* showing significant gene flow into a small remnant population over scales >1km. Arrows represent pollen sources received by trees. Coloured portions of arrows indicate the proportion of seed pollinated by trees within the population with the same colour, white portion of arrows indicate proportion of seed pollinated by other trees from outside the population.



What does this mean for landscape management?

Based on the key findings, a number of recommendations that are broadly applicable to maintaining the ecological and genetic viability of remnant vegetation can be made.

1. **Maintain populations larger than 100-200 reproductive plants where possible.**

   Larger reproductive populations have better rates of reproduction, harbour greater genetic diversity and have less inbreeding than smaller populations.

2. **Minimise isolation between populations.**

   Neighbouring populations rely on each other for gene flow and seed dispersal, which helps maintain fitness and reproduction. Nearby populations may also act as stepping stones for pollinators and help to maintain gene flow among populations.

3. **Site condition was not a useful indicator of remnant responses to fragmentation.**

   The study found site condition such as high species diversity and weed cover were not good indicators of genetic and demographic performance.

4. **Populations should be managed on the landscape level rather than as a series of populations independent of other vegetation in the area.**

   Biological connectivity between remnant populations must to be considered in remnant management and restoration activities.

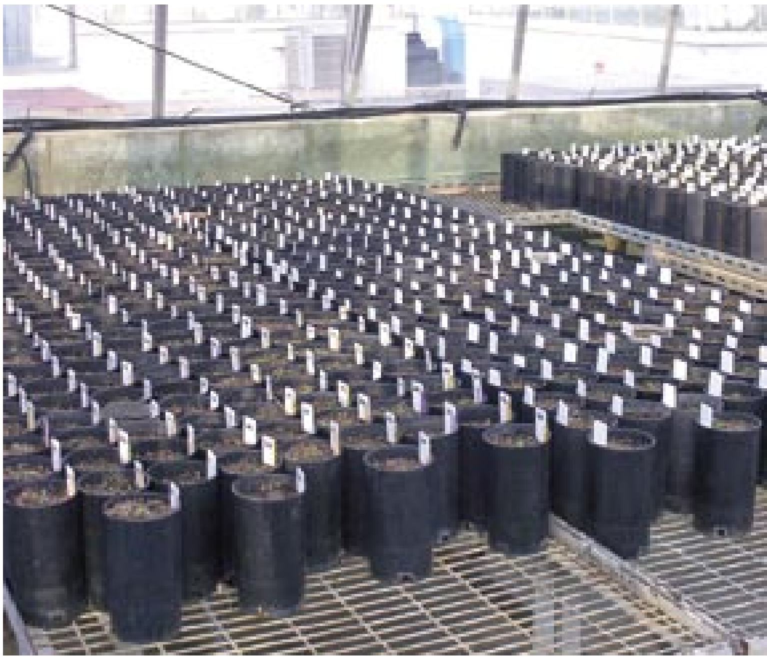
Measuring plant density estimates within a population of *Acacia dealbata*

Eremaea pauciflor - one of the species studied in the kwongan site

Swainsona sericea - flowers from a growth trial

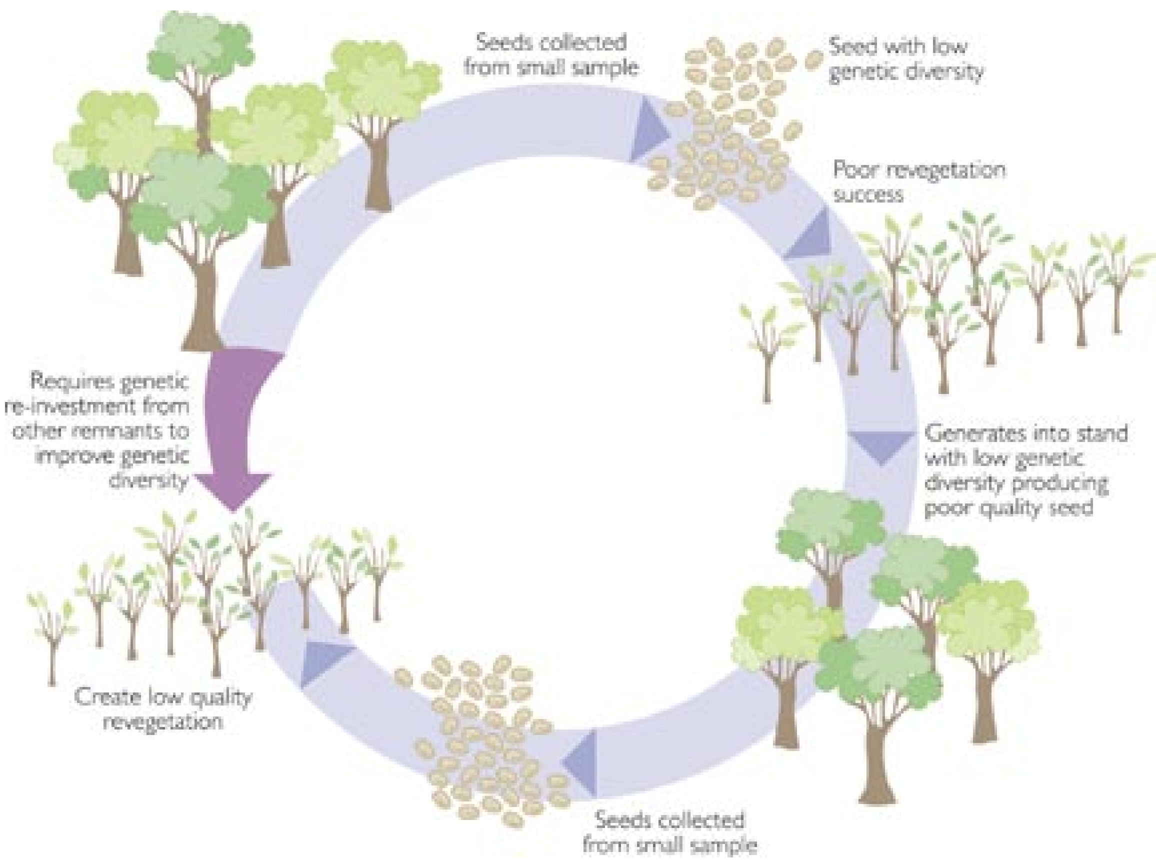
Remnants as seed sources

Choosing which remnants to use as seed sources is important for restoration success and to generate future high quality seed sources that do not show negative effects associated with inbreeding. This study indicates that, where possible, collections should be taken from large populations as these will provide genetically diverse seed that will generate higher quality revegetation sites (See Fig. 4a & 4b). When this is not possible, smaller populations should be combined to ensure that the newly restored populations have high genetic diversity to limit inbreeding effects as plants become reproductive.



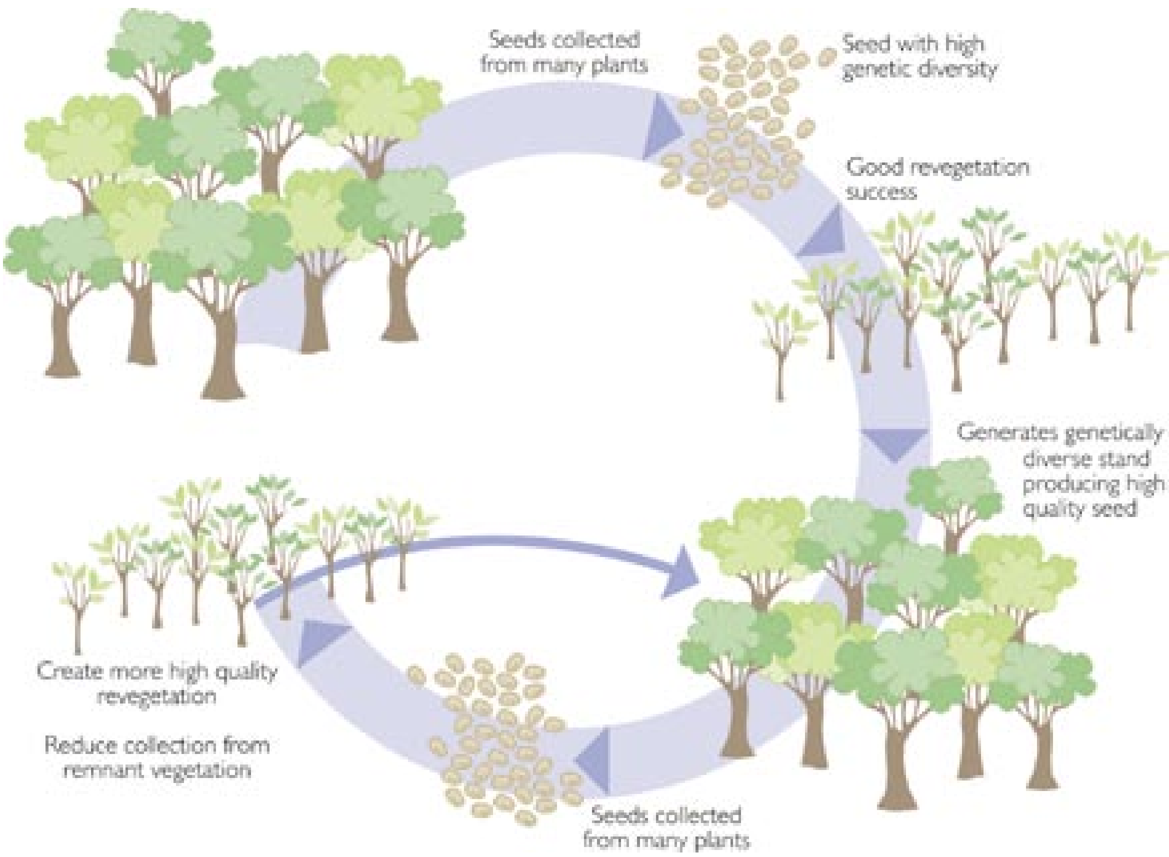
Seedlings emerging from growth trials to assess plant fitness

Figure 4a Small population seed source [<100-200 plants]



These seedlings from potted trials show a number of plants with low vigour as a result of low genetic variability.

Figure 4b Large population seed source [>100-200 plants]



Knowledge gaps

While the results of this project have led to a set of recommendations that are widely applicable to different ecosystems, further research is still required to improve our understanding of the genetic and ecological responses of Australian native plants to ecosystem fragmentation.

Researchers have identified five key issues that are particularly important and yet remain poorly understood.

The frequency, extent and scale of genetic and demographic connectedness among populations

Understanding how far and how frequently populations rely on each other for gene exchange through pollen flow and seed dispersal will help finetune guidelines on how to manage populations at landscape levels. It will also help to generate landscape 'maps' to determine where revegetation efforts will be most effective to ensure these linkages are maintained or improved. This is the subject of a current Land & Water Australia funded project "Understanding genetic constraints to vegetation persistence in fragmented landscapes (Project number CPI13)".

The influence of life-history traits or ecological 'type' on sensitivity to fragmentation

The target species showed different genetic and demographic responses to fragmentation and further research is required to determine whether the findings of this study are broadly applicable to species with similar life-history traits.

The medium-term effects of accumulated inbreeding through matings between close relatives

Increased matings between related individuals in small populations have the potential to increase the 'genetic load' of these populations, exposing them to deleterious gene combinations. This increased genetic load will limit the long term future of these populations by reducing future seedling quality.

How well does geographical genetic structure predict adaptively important traits?

Understanding associations between adaptive traits and genetic structure is required to establish the geographic scale over which genes can be transported without impacting on locally adapted populations, or resulting in poor restoration success due to seed being poorly adapted.

The importance of gross cytogenetic differences within key restoration species

Further cytological research is required to ensure that incompatible genotypes are not brought together during revegetation efforts, as this will likely generate sterile offspring.

A tagged branch of *Acacia dealbata* which allows researchers to measure and compare sequentially the numbers of flowers set within the flower spike, the number of flowers actually fertilised and that then result in seed formation

Useful references for further reading

Broadhurst LM, North T, Young AG (2006) Should we be more critical of remnant seed sources being used for revegetation? *Ecological Management and Restoration* **7**, 211-217.

Broadhurst LM, Young AG (2006) Reproductive constraints to the long-term persistence of fragmented Acacia dealbata (Mimosaceae) populations in southeast Australia. *Biological Conservation* **133**, 512-526.

Broadhurst LM, Young AG (2007) Seeing the wood and the trees - predicting the future for fragmented plant populations in Australian landscapes. *Australian Journal of Botany*.

Broadhurst LM, Young AG, Thrall PH, Murray BG (2006) Sourcing seed for *Acacia acinacea*, a key revegetation species in south-eastern Australia. *Conservation Genetics* **7**, 49-63.

Byrne M., Elliott C.P., Yates C. and Coates D.J. (2007) Extensive pollen dispersal in a bird-pollinated shrub, *Calothamnus quadrifidus*, in a fragmented landscape. *Molecular Ecology* **16**, 1303-1314.

Byrne M., Elliott C., Yates C. and Coates D. (2007) Extensive pollen dispersal in *Eucalyptus wandoo*, a dominant tree of the fragmented agricultural region in Western Australia. *Conservation Genetics* In press

Coates D. J., Byrne M., Elliott C., Sampson J. and Yates C. (2005) Gene flow and outcrossing in a fragmented landscape: implications for seed sourcing from small remnants. In *Proceedings of the Fifth Australian Workshop on Native Seed Biology*. Eds Adkins, S., Bellairs, S. and Coates D. Australian Centre for Minesite Rehabilitation. Brisbane, pp 37-45.

Elliott, C and Byrne, M. (2006) Isolation and characterisation of microsatellites in the woody shrub, *Calothamnus quadrifidus* (*Myrtaceae*). *Molecular Ecology* **5**, 757-759.

Young A.G. (2005) Non-provenance genetic issues for native seed sourcing. In *Proceedings of the Fifth Australian Workshop on Native Seed Biology*. Eds Adkins, S., Bellairs, S. and Coates D. Australian Centre for Minesite Rehabilitation. Brisbane.

Yates, C.J., Coates, D.J., Elliot, C. and Byrne, M. (2007) Bird pollination and mating system variation for a shrub in fragments of species rich kwongan in south-west Western Australia. *Biodiversity and Conservation* in press.

Yates C.J., Elliott C., Byrne M., Coates D.J. and Fairman R. (2007) Seed production, germinability and seedling growth for a shrub in fragments of species rich kwongan in south-west Australia. *Biological Conservation* **136**, 306-314.

A valuable intact native grassland site preserved in cemetery grounds containing *Swainsona* species

Australian Government
Land & Water Australia

Managing genetic diversity in remnant vegetation

Published by	Land & Water Australia
Postal address	GPO Box 2182, Canberra ACT 2601
Office Location	L1, The Phoenix 86 Northbourne Ave, Braddon ACT
Telephone	02 6263 6000
Facsimile	02 6263 6099
Email	Land&WaterAustralia@lwa.gov.au
Internet	This fact sheet provides results from a research project CPI10 funded through the Native Vegetation R&D program. For more detail on the research project, please visit **http://www.lwa.gov.au/nativevegetation/**

Design	Mariana Rollgejser
Print	Goanna Print
Product code	PK071323