Banksia Woodland Restoration Project

Annual Report 6

January - December 2017




Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

PARKS AND WILDLIFE SERVICE

Mark Brundrett, Vanda Longman, Anna Wisolith, Karen Jackson, Margaret Collins and Karen Clarke
Department of Biodiversity, Conservation and Attractions

Department of Biodiversity, Conservation and Attractions
Locked Bag 104
Bentley Delivery Centre WA 6983
Phone: (08) 9219 9000
Fax: (08) 9334 0498
www.dbca.wa.gov.au

This report was prepared by Mark Brundrett, Vanda Longman, Anna Wisolith, Karen Jackson, Margaret Collins and Karen Clarke.

Questions regarding the use of this material should be directed to:
Karen Clarke
Swan Region, Crawley
Department of Biodiversity, Conservation and Attractions
Locked Bag 104, Bentley Delivery Centre WA 6983
Phone: 9442 0300
Email: karen.clarke@dbca.wa.gov.au

Project Team 2011-2017: Mark Brundrett, Anna Wisolith, Vanda Longman, Karen Jackson, Karen Clarke, Sapphire McMullan-Fisher, Julie Fielder, Margaret Collins, Alice O'Connor, Tanya Llorens, Tracey Moore, Tracy Sonneman, Julia Cullity, Karen Bettink, Brett Glossop and Mathew Woods.

Acknowledgements:
Thank you to the following volunteers who kindly donated their time to help us with our field work in 2017: Tim Barling, Rebekah Bigaila, Stephanie Floeckner, Emma Frost, Mark Hutchison, David James, Leah Knapp, Kylie Payne, Jim Prince, Xiubin Qi, Dan Rogers, Cate Tauss and Erich Volschenk. We received assistance with spatial information and other aspects of our project from Ricky van Dongen, Bart Huntley and Natasha Tay. Seed collections were managed by Anne Cochrane, Andrew Crawford and Anne Monaghan of the Threatened Flora Seed Centre.

The recommended citation for this publication is:
Brundrett M, Longman V, Wisolith A, Jackson K, Collins M, Clarke K. 2018. *Banksia Woodland Restoration Project: Annual Report 6: January - December 2017*. Department of Biodiversity, Conservation and Attractions, Perth.

Abbreviations:

- BWR – Banksia Woodland Restoration Project (this project)
- CBC – Carnaby's cockatoo, Carnaby's black cockatoo (*Calyptorhynchus latirostris*)
- CoC – City of Cockburn
- Completion Criteria – numeric targets or milestones for restoration projects used to report outcomes
- DEC – the Department of Environment and Conservation, later the Department of Parks and Wildlife and now the Department of Biodiversity, Conservation and Attractions
- DBCA – Department of Biodiversity, Conservation and Attractions
- DPLH – Department of Planning, Lands and Heritage
- DRF – Declared Rare Flora
- JAH – Jandakot Airport Holdings Pty Ltd
- PURSAC – Perth Urban Restoration Scientific Advisory Committee
- Restoration – in this report refers to creating new habitat by establishing a specific type of native vegetation in totally cleared areas within the conservation estate. More generally Ecosystem Restoration is the "process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (SER 2004).
- RP – Regional Parks (Department of Biodiversity, Conservation and Attractions)
- SAC – Scientific Advisory Committee
- SCD – Swan Coastal District (Department of Biodiversity, Conservation and Attractions)
- SCP – Swan Coastal Plain
- TEC – Threatened Ecological Community
- TFSC – Threatened Flora Seed Centre (Department of Biodiversity, Conservation and Attractions, Kensington)
- UN – Urban Nature Program (Department of Biodiversity, Conservation and Attractions)
- WAPC – Western Australian Planning Commission

Executive Summary

The Banksia Woodland Restoration (BWR) Project is managed by the Department of Biodiversity, Conservation and Attractions (DBCA) to create new banksia woodlands, and repair existing woodlands in the Perth metropolitan area, especially as habitat for both the nationally threatened Carnaby's cockatoo (*Calyptorhynchus latirostris*) and the grand spider orchid (*Caladenia huegelii*). In 2016, "Banksia Woodlands of the Swan Coastal Plain" were also listed as nationally threatened, further strengthening the need to protect, manage and restore these plant communities. In 2011, offset funds from Jandakot Airport Holdings Pty Ltd (JAH) established the BWR project as part of the Commonwealth's ministerial conditions to offset the impacts of clearing 167 ha of banksia woodland at Jandakot Airport, Perth, Western Australia. Now managed by the Department of the Environment and Energy, this offset requires JAH to provide DBCA with funding of $9,200,000 for "rehabilitation and conservation activities in banksia woodland within 45 km of the airport".

The BWR project was established in September 2011 and has initiated large-scale restoration and rehabilitation works in banksia woodlands on the Swan Coastal Plain (SCP) within the conservation estate of the Perth Metropolitan Region. The main objectives of this project are to:

1. Restore banksia woodland by creating and repairing lands within the conservation estate.
2. Select areas for restoration using a prioritisation process based on conservation values and threatening processes, especially in relation to habitats for Carnaby's cockatoos and the grand spider orchid.
3. Use scientific approaches to improve the cost effectiveness of restoring banksia woodlands.
4. Improve methods for restoration by applying knowledge gained from monitoring outcomes.
5. Maximise the area of banksia woodland created or repaired by efficient resource allocation.
6. Develop monitoring protocols for assessing banksia woodland biodiversity and condition.
7. Support community groups in managing banksia woodlands.
8. Collate and share information on banksia woodland biodiversity, condition and management.

Works undertaken or underway for the BWR project in the first six years include:

1. Selection of restoration sites using a comprehensive prioritisation process based on the objectives of the project.
2. Establishment of 50 ha of new banksia woodland in areas without native vegetation using various combinations of topsoil transfer, direct seeding and planting of seedlings. Of this, a total of 16 ha received topsoil directly transferred from Jandakot Airport.
3. Management of threatening processes in existing banksia woodland to protect habitat and improve vegetation condition in 25 sites (locations shown in the Map below) including:
    a. Control of the most serious environmental weeds in over 600 ha of bushland in 23 sites.
    b. Fencing of 12 km of reserve boundaries to reduce illegal access and associated threatening processes such as spread of *Phytophthora* dieback.
4. Establishing a network of 31 plots at five sites for monitoring biodiversity and vegetation condition in banksia woodland to determine the long-term outcomes of weed management and recovery from bushfire.
5. Providing funding, seeds, seedlings and advice to community groups and local governments for banksia woodland restoration at 19 locations.
6. Enhancing conservation of the grand spider orchid (*Caladenia huegelii*) through translocations and population surveys.

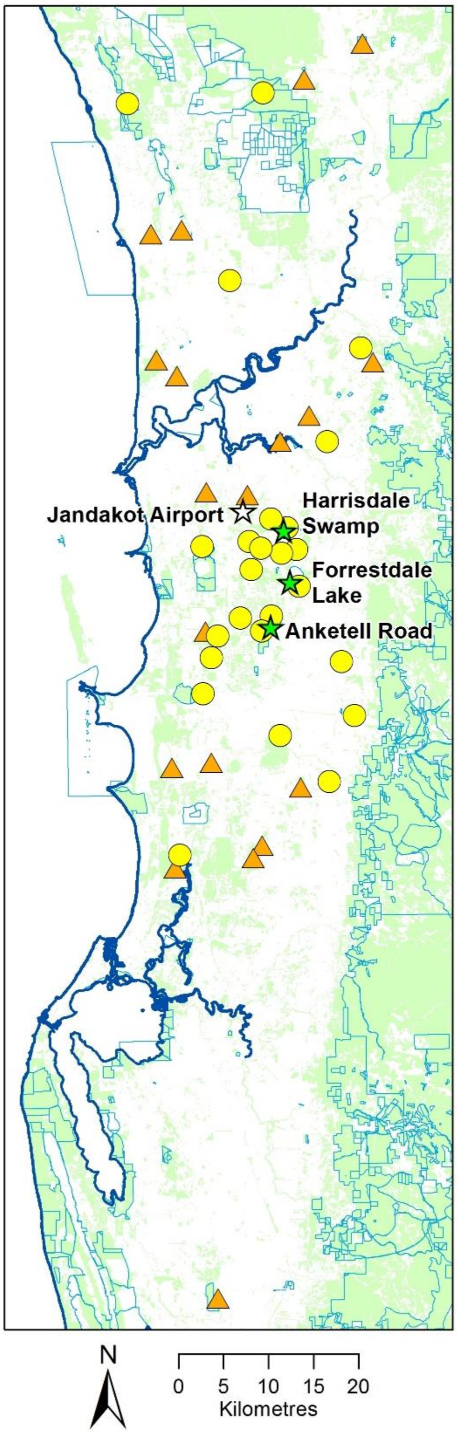
In 2014, JAH renegotiated the offset with the Commonwealth leading to amended ministerial conditions that modified the annual payment schedule so that future payments were only required when parcels of land were cleared for development. This change to ministerial conditions significantly affected the BWR project from 2015 onwards, by interrupting land management operations, research trials and staffing. As of 2018 96% of the funding has been received, with $383,333 associated with the final seven hectares of clearing at Jandakot Airport still outstanding (expected in 2020 or later). In 2017/18 a major restructure of state government departments led to further changes to the BWR project. The project will be transitioning after June 2018 into a long-term monitoring project for restoration sites and banksia woodland.

For restoration of banksia woodland in completely degraded areas, two sites with a total area of 50 ha were selected that were dominated by weeds. These are Anketell Road in Jandakot Regional Park and Forrestdale Lake (see Map and Table). Flora surveys of reference sites provided plant diversity and density targets required to evaluate restoration success and plan seed collection and nursery orders. These reference sites were at Jandakot Airport (where the topsoil was sourced) and adjacent to the restoration sites.

To support restoration works, the BWR project worked with DBCA's Threatened Flora Seed Centre to manage seed collections and resolve problems with seed germination for some species. A major seed resource has been established with over 1,200 seed accessions for 164 species, of which 341 accessions were sent to nurseries, 550 were used for direct seeding, and 216 were provided to community groups or other restoration projects.

Restoration at Anketell Road and Forrestdale Lake included 16 ha of topsoil transfer in April-May 2012, 40 ha of planting of nursery-raised seedlings from 2012 to 2015, and some hand direct seeding (see Table below). In total, more than 46,000 nursery-raised local provenance native seedlings were planted. In 2014 and 2016 an additional 16.5 ha was direct seeded using machinery by Greening Australia WA.

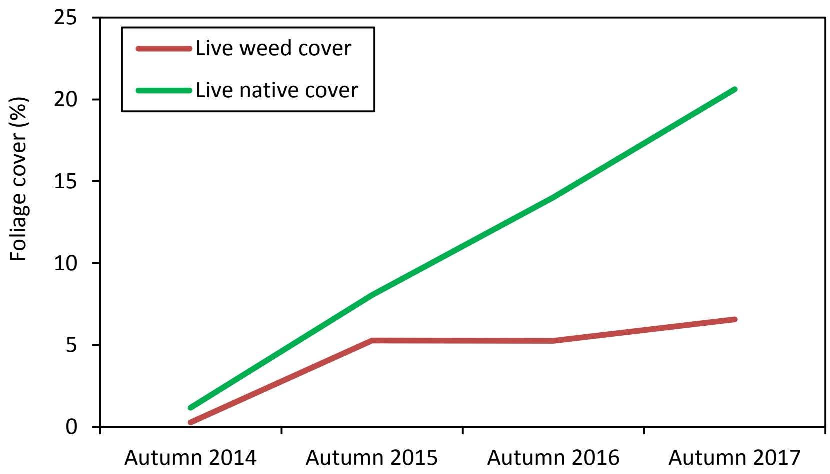
In total, 162 species of native plants grew in the restoration sites, of which 115 came from the topsoil seed bank and most others were from planting and direct seeding. At both sites, native plant germination from topsoil peaked at over 700,000 stems per ha in 2013, then declined substantially due to extremely hot and dry summers. By late 2017 native perennials had reached an average density of 20,000 stems per ha, well exceeding the target density of 7,000 stems per ha, but results were highly variable. Plant density targets were reached in 70% of monitoring plots with topsoil by the summer of 2016/2017. Target density of 250 stems per ha of banksias (for Carnaby's cockatoo food plants) was reached in most areas, but later declined to 150-220 stems per ha due to drought mortality. Native plant cover in these areas increased gradually to 20% by 2017 and perennial weed cover stabilised at around 5% (see Graph). Areas established by direct seeding and planting only had lower plant diversity and cover than areas with topsoil, but also had higher tree density. All of the areas require some ongoing weed management, particularly for couch grass (*Cynodon dactylon*). Future monitoring will be needed to confirm a self-sustaining ecosystem develops, determine which restoration methods were most successful and cost effective, as well as to inform future management. These data are also required to measure the overall cost of establishing banksia woodland with a diverse understory and resilient tree canopy.



Map *showing Banksia Woodland Restoration Project locations in the Perth Metropolitan Region relative to Jandakot Airport (white star). These include three restoration areas: Anketell Road, Forrestdale Lake and Harrisdale Swamp (green stars), sites for weed and other management (yellow circles), and funding provided to community groups for the restoration or repair of banksia woodlands (orange triangles). This map also shows remnant vegetation (light green shading) and reserves managed by the Department of Biodiversity, Conservation and Attractions (light blue boundaries).*

Table showing the extent of each restoration method in hectares at the two restoration sites. Note: planting and direct seeding overlapped in various combinations therefore total areas restored are not sums of each method.

Restoration method	Timing	Anketell Rd (ha)	Forrestdale Lake (ha)	Total restored by method (ha)
Topsoil transfer	2012	11.5	4.5	16
Planting	2012 - 2015	32	7.5	39.5
Direct seeding	2012, 2014, 2016	15.5	1	16.5
Total area restored*		**39**	**11**	**50**



Graph showing vegetation cover trends over four years for areas with respread topsoil in the largest restoration site at Anketell Road. The increase in native plants is a result of seed germination and planting, while weed cover (mainly perennial veldt grass *Ehrharta calycina* and couch *Cynodon dactylon*) has remained fairly stable over the last three years but may require ongoing management.

In 2017, the BWR Project was commissioned by the Department of Planning, Lands and Heritage to help manage restoration of a highly degraded 7 ha area at the southwestern boundary of Harrisdale Swamp. Topsoil was harvested after clearing at Jandakot Airport and respread at the Harrisdale in May 2017. We monitored 24 quadrats to provide baseline data for weed management and restoration and obtained seed. The BWR project also had a major role in establishment of the Roe 8 corridor restoration project, by helping to develop the restoration plan and monitoring programs, as well as providing training in restoration monitoring for community group members and university students.

The second major component of the BWR project is to undertake management to improve the condition of existing banksia woodland in the conservation estate. Sites for management actions such as weed control and fencing were selected after a strategic assessment of banksia woodland areas on the Swan Coastal Plain, site visits and weed mapping. Weed control using selective herbicides for perennial veldt grass (*Ehrharta calycina*) and other major environmental weeds occurred at 27 sites within 23 reserves from 2013 to 2017 (over 600 ha in total - see Map). Offset funding was also used to establish the Perth Banksia Woodland Community Restoration Grants, which has provided $300,000 to community groups for restoration, weed management or dieback control at 19 additional locations in 2015 (see Map).

A banksia woodland monitoring program was established in 2013 to measure changes to plant diversity, cover, density and condition following perennial veldt grass control (31 plots at five locations). Effective weed control initially increased the dominance of annual plants, as well as some perennial native plants and banksia seedlings. Fauna monitoring in restoration areas and banksia woodland reference sites established that there were few native mammals, but substantial numbers of birds, reptiles and amphibians in all areas and that these were already beginning to use the restoration sites.

A severe bushfire in Banjup in February 2014 burnt seven monitoring plots in Shirley Balla Swamp. This created an opportunity to study the impact of fire on banksia woodland plant diversity, cover and density. There was a 39% mortality rate for banksia trees, but also a very high rate of post-fire germination of banksia seed (6,000 seedlings per ha). Post-fire, more plant species recovered by seed germination than through resprouting, however the latter resulted in greater foliage cover. Major benefits to native plants cover and diversity due to weed management were also measured post-fire.

Table of Contents

1. Introduction and Background

The Jandakot Airport Offset Plan was developed in 2010 by Jandakot Airport Holdings Pty Ltd (JAH) as an offset for the clearing of up to 167 ha of native vegetation at Jandakot Airport in Western Australia. The approval for this expansion of Jandakot Airport was subject to a number of conditions specified in the EPBC 2009/4796 approval document (Government of Australia 2010). The conditions of the approval need to be fulfilled to the satisfaction of the Commonwealth Department of the Environment. In addition to banksia woodland restoration (Condition 4b), the offset also funded the acquisition of Carnaby's cockatoo (*Calyptorhynchus latirostris*) feeding habitat (Condition 4c), Carnaby's cockatoo recovery actions (Condition 4e) and *Caladenia huegelii* research by the Botanic Gardens and Parks Authority (Condition 6e). This report only concerns Condition 4b which was supported by payment of $9,200,000 to the Department of Environment and Conservation (DEC), now the Department of Biodiversity, Conservation and Attractions (DBCA), for the restoration and rehabilitation of banksia woodland within 45 km of Jandakot Airport. A memorandum of understanding between JAH and DEC, signed in 2011, set out the manner in which they would work together to satisfy Condition 4b. In 2011, DEC initiated the Banksia Woodland Restoration (BWR) project to undertake these tasks. In 2016 "Banksia Woodlands of the Swan Coastal Plain" were also listed as nationally threatened further strengthening the need to protect, manage and restore these ecosystems.

Approximately 66% of the native vegetation in the Swan Coastal IBRA Bioregion has been cleared, much of which was banksia woodland (Local Biodiversity Program 2013). In the Perth Metropolitan area, less than a quarter of the original banksia woodland remains and all of this is potential Carnaby's cockatoo (CBC) feeding habitat. The BWR project has the overall objective of increasing the area and improving the condition of banksia woodlands with similar biodiversity values to the Jandakot Airport woodlands, to help mitigate the most significant impacts from clearing this location. These impacts include the loss of CBC feeding habitat and habitat for the endangered orchid *Caladenia huegelii.* The BWR project has the following principal objectives:

1. Restore banksia woodland by creating new vegetation and repairing existing woodland within the conservation estate.
2. Select areas for management using a ranking process based on environmental values, especially concerning habitats for CBC and *Caladenia huegelii*.
3. Use scientific approaches to maximise the cost effectiveness of ecosystem management.
4. Improve methods for rehabilitation using knowledge gained by monitoring outcomes.
5. Maximise the area of banksia woodland restored or managed by efficient resource allocation.
6. Develop monitoring protocols and criteria for assessing banksia woodland condition and biodiversity.
7. Support community groups who help to manage banksia woodlands.
8. Collate and share information on banksia woodland biodiversity and condition.

The BWR project has initiated large scale natural habitat restoration and rehabilitation work in the conservation estate to meet the objectives listed above. These actions target banksia woodland habitats in the Perth Metropolitan Region, giving highest priority to areas most similar to those at Jandakot Airport as well as areas of very high conservation value such as Threatened Ecological Communities. The site prioritisation process and the establishment of reference plots used to provide targets for restoration are described in separate reports (Brundrett et al. 2017, Clarke et al. 2017). Management actions include:

1. Site selection following a rigorous criteria-based ranking process.
2. Establishment of new banksia woodland in cleared areas using topsoil from Jandakot Airport, direct seeding and planted seedlings.
3. Banksia woodland rehabilitation to protect and substantially increase areas in good condition through:
    a. Weed management of bushland to control the most serious environmental weeds.
    b. Fencing of reserve boundaries to reduce illegal access and the associated disturbance and rubbish dumping, as well as weed and *Phytophthora* dieback spread.
    c. Infill planting of banksia trees in areas where existing native canopy cover is sparse.
4. Establishing a network of banksia woodland condition monitoring sites.

5. Providing support for community groups or local government to do any of the above.

1.1. Issues with Offset Funding and Long-Term Restoration Outcomes

For this project, a large portion of the offset funding arrived at the beginning, with subsequent payments delayed by changes in the schedule of clearing at Jandakot Airport. In 2014, JAH renegotiated the offset with the Commonwealth and the ministerial conditions for the offset were amended as a variation to approval EPCB 2009/4796 (Department of the Environment 2014). This allowed JAH to postpone payments to the department until clearing occurred, rather than make annual payments from 2010-2015 as agreed under the original schedule with a 5-year deadline to finalise payment (Department of the Environment 2014) (Fig. 1). This major change to the offset, without consultation with the department, significantly affected the project from 2015 onwards. It created uncertainty about completion of project objectives, loss of continuity of land management operations and research trials, and caused major disruption to staffing the specialist restoration team. A major factor in the department originally committing to this third-party offset was the 5-year funding schedule and limit to finalisation of payment.

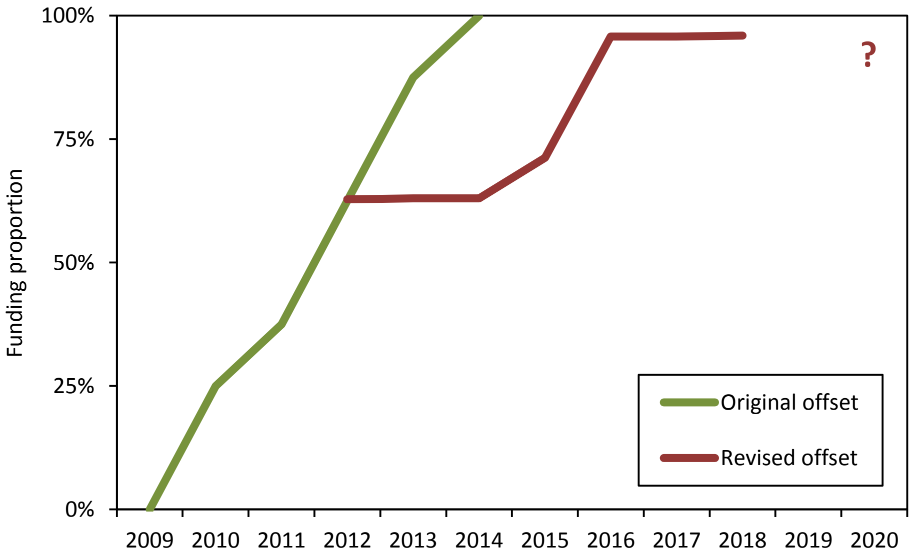


Figure 1. The original 5-year staged funding schedule (green) of the Jandakot Airport Offset and the revised schedule of funding (red) under the amended offset, determined by on-ground clearing operations at Jandakot Airport. The question mark above 2020 indicates the earliest the final payment is expected.

As shown in Figure 1, funding was interrupted between 2012 and 2015 when a relatively small area of Jandakot Airport (14 ha) was cleared, resulting in a small interim payment to the department. This allowed re-employment of key staff and some limited restoration activities to continue into 2016. In July 2016, the Commonwealth Department of the Environment and Energy conducted a Compliance Audit at Jandakot Airport of approval conditions under EPCB 2009/4796 (and EPBC 2013/7032). During the audit, JAH confirmed they were committed to payment of the full $9.2 million to DBCA. The department advised that full or partial payment was required before the end of September 2016 for the BWR Project to continue and allow key objectives to be achieved as required by the ministerial conditions of the offset (EPCB 2009/4796).

In August 2016, JAH paid a further $2.3 million to the department (Fig. 1). This allowed the specialist restoration team to be retained and ongoing restoration works to be continued. However, the delays and changes to funding had already affected project outcomes significantly. To date, 96% of the agreed funding has now been received (Fig. 1). A total of $383,333 remains outstanding associated with the final seven hectares of clearing at Jandakot Airport. Timing of this payment is under negotiation with JAH and is expected at the earliest in 2020 (Fig. 1). In 2017 a major restructure of state government departments led to further changes to the BWR project. The project will be transitioning after June 2018 into a long-term monitoring programme for restoration sites and banksia woodland.

2. Seed Management and Germination Research

Restoring banksia woodland is difficult because some of the most important species, including banksias, do not usually recruit from topsoil and so must be introduced through direct seeding or by planting tubestock. However, growing plants from seed can also be challenging as many species have low seed availability, poor seed viability, or are difficult to germinate. Seed collecting is a major expense for all restoration projects and seed quality assessment is required to ensure this activity is undertaken efficiently. The BWR project set up a collaboration with DBCA's Threatened Flora Seed Centre (TFSC) to organise and store the large quantities of incoming seed, as well as to quantify the seed, assess its quality through germination testing, prepare seed batches for direct seeding and nursery orders, and to conduct trials testing different germination and storage conditions. This research will be useful for maximising germination and ensuring efficient use of seeds, which are an expensive resource in restoration. Work at the TFSC was managed by Anne Cochrane and Andrew Crawford.

Seed collected from the Coastal Plain for this project includes large quantities of seed from Jandakot Airport and over 50 other locations (Table 1). Over the project, 1,238 accessions of seed from 164 species have been received. Germination testing to confirm viability of 607 accessions of 87 species has also been conducted. Seed collections to supply nursery orders and direct seeding for the BWR project, as well as other restoration projects are stored at the TFSC in a refrigerated and humidity-controlled environment. Currently there are 680 accessions of 135 different species (totalling 100 kg) in storage where they will remain available for use by restoration projects. Over the life of the project, over 30 kg of seed (excluding *Macrozamia* seed) from over 80 species have been used for direct seeding (Table 2). Approximately 6.4 kg of seed from 49 species have been sent to nurseries resulting in over 46,000 plants (Table 3). The BWR project also provided seed to two other major restoration projects for the Roe 8 corridor and Harrisdale Swamp in 2017/18 (Table 2), and also to support seven community group or local government restoration projects.

Table 1. Seed inputs and outputs of the TFSC for the BWR project from 2011-2018, including seed quantified and germination tested, as well as seed placed into long-term freezer storage.

	Number of Accessions	Number of Species
Total collections received 2011-2018	1,238	164
Germination tested 2011-2018	607	87
Accessions currently in storage	680	135
Nursery total	341	49
Direct seeding total	550	83
Seed given to other projects	216	59

Table 2. Amounts of seed (g) used for direct seeding by year and location (excluding over 30 kg of *Macrozamia* seed).

Year	Anketell Road	Forrestdale Lake	Roe 8	Harrisdale Swamp (planned)	All sites
2012	2,403	593	-	-	2,996
2013	3,508	-	-	-	3,508
2014	10,359	-	-	-	10,359
2016	13,606	777	-	-	14,383
2017/18	-	-	629	1,400	2,029
TOTAL	**29,876**	**1,370**	**629**	**1,400**	**33,275**

Table 3. Total number of nursery-raised tubestock planted over four years at Anketell Road, Forrestdale Lake and Pony place (a small restoration area near Anketell Road).

Year	Anketell Road	Forrestdale Lake	Pony Place	All sites
2012	2,867	2,252	-	5,119
2013	8,287	4,425	175	12,712
2014	12,136	5,256	467	17,392
2015	9,474	1,337	425	11,236
TOTAL	**32,764**	**13,270**	**1,067**	**46,459**

2.1. Banksia Seed Germination Trials

In 2015, a research trial was set up to try to increase the speed and reliability of banksia seed germination in the field. A total of 1,440 *Banksia attenuata* seeds were planted across four plots at Anketell Road. Half the seeds were pre-soaked in water, while the other half was untreated (control). In addition, two sowing times (June and July) were compared. In 2016 the trial was repeated using the same methods but using earlier sowing times (May and June).

In both the 2015 and 2016 trials, the pre-soaked seeds emerged faster and with a total emergence 6-7% higher than the control seeds (data not shown). Despite these quicker germination times and greater total emergence of the pre-soaked seedlings, all seedlings started dying off in large numbers over their first spring and summer. Seedling deaths commenced shortly after emergence, with mortality from June to October (Fig. 2) primarily caused by snail and insect herbivory, as evidenced by chewing damage to cotyledons that were partly or completely eaten. Seedling deaths peaked from October 2016 to March 2017. This coincided with rapidly declining rainfall (see Section 4.1) which presumably caused major drought stress. In total around 60% of seedlings died before the end of their first summer (Fig. 2). By March 2017 (44 weeks after seeding), average survival of emerged seedlings across all treatments was only 4% for the 2016 trial. These trials occurred in four areas at Anketell Road with very low plant density. It is possible that poor plant establishment indicates unidentified soil or hydrological problems in these areas, though previous results from other trials elsewhere suggest that low survival of banksias is fairly typical everywhere at this site, especially due to severe drought in late spring and summer.

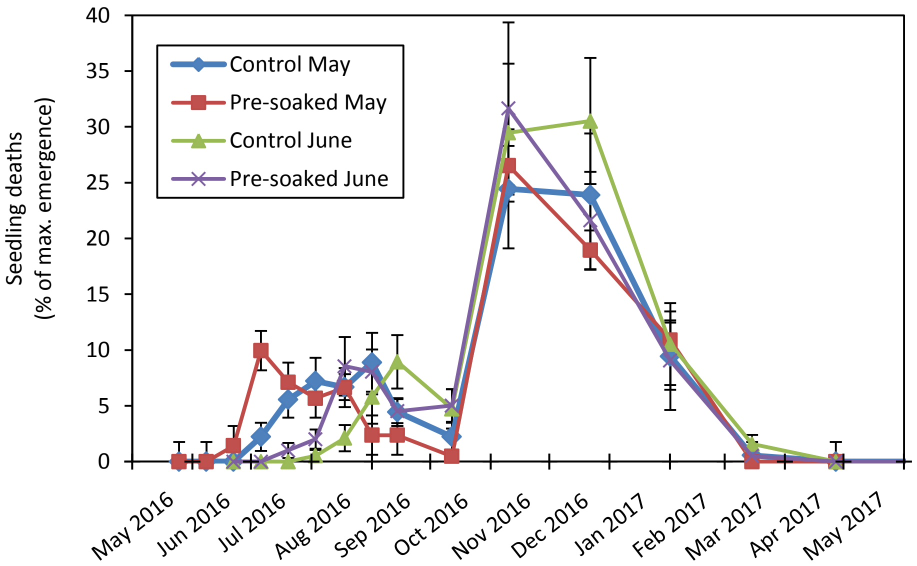


Figure 2. Seedling deaths from the 2016 banksia seed germination trial. Deaths that occurred from June to October are thought to be largely caused by snail and insect grazing, with a peak in deaths occurring from October to March due to drought stress.

3. Banksia Woodland Restoration

Restoration activities covered a total of 50 ha at Anketell Road and Forrestdale Lake between 2012-2016 (Table 4). Figures 3 and 4 show the extent and layout of restoration works at these sites. Transferred topsoil was spread across 11.5 ha at Anketell Road and 4.5 ha at Forrestdale Lake. In 2012, small areas of the transferred topsoil at both sites totalling 2.5 ha were direct seeded as a trial run. Between 2012-2015, planting at each site took place in both topsoil and non-topsoil areas, with a total of 32 ha at Anketell Road and 7.5 ha at Forrestdale Lake. At Anketell Road, 22 ha of land was restored in non-topsoil areas, of which 13 ha were direct seeded and planted, and 9 ha were planted only. At Forrestdale Lake, around 2.5 ha of already vegetated areas (non-topsoil areas) were infill planted with overstory species. More details on each restoration activity are described below.

3.1 Topsoil Transfer

The Department received notification from JAH in September 2011 that they planned to clear Precinct 5 in early 2012, an area of 42 ha that included about 20 ha of suitable excellent to very good condition banksia woodland. This was a year ahead of the original schedule in the offset plan. This provided the only opportunity to use transferred topsoil to restore banksia woodland, since topsoil in other areas at Jandakot Airport was either no longer available or scheduled for clearing years later (Section 1.1). Consequently, DBCA was required to rapidly develop a soil transfer tender and select recipient sites that totalled approximately 20 ha.

All areas restored by topsoil transfer initially were open, weed-dominated fields at Anketell Road and Forrestdale Lake (Fig. 6). Topsoil from Jandakot Airport was spread to a uniform depth of either 50 or 100 mm in April-May 2012 after a thin layer of existing topsoil (5-10 cm) was scraped off to reduce the weed soil seed bank. Topsoil from Jandakot Airport was only applied to upland areas, as it contained seeds of species unsuited to dampland habitats. At Anketell Road, 11.5 ha received transferred topsoil and at Forrestdale Lake 4.5 ha. Control of grazing animals was found to be essential, so rabbit-proof fencing was installed around 26.5 ha of land to protect the direct seeded areas, and most of the topsoil and planted areas (Figs. 3, 4).

3.2 Planting and Weed Control

The first planting took place in 2012 after the topsoil transfer, with larger planting and seeding programs from 2013-2015 (Table 4). At both sites, separate species lists were used for planting and direct seeding in upland and transitional dampland areas. These lists resulted from the assessment of flora and vegetation in reference sites that ranked species according to their importance in each zone (Brundrett et al. 2017). All seeded and planted species are listed in Appendix 2.

A total of over 46,000 plants were planted over four years (2012-2015) at Anketell Road and Forrestdale Lake (Table 3). Nursery orders primarily consisted of trees and shrubs with canopy-stored seed that were unlikely to regenerate from topsoil. Tubestock was planted by DBCA staff, volunteers from the Friends of Forrestdale, as well as Ecojobs (Green Skills Inc.) and Green Army crew members.

Most planting occurred within the fenced areas, though some tubestock was planted with tree guards outside fences to infill sparse canopy in vegetated areas at Forrestdale Lake (orange areas in Fig. 3), and to increase restored areas at both sites (unfenced shaded areas in Figs. 3 and 4). Survival of these plants was very low in most areas due to drought and grazing, despite the use of tree guards. For example, in the two largest planted and unfenced areas at Anketell Road (shaded orange in Fig. 4), survival was extremely low in the western area (below 1%) with only one surviving plant, and in the eastern area, survival was approximately 10% with 57 surviving plants (resulting in a density of only 20 stems per ha). These areas were mostly planted with trees that should eventually help to restore canopy cover, although further work may be required to improve areas with the worst survival rates.

Work to manage weeds in restoration areas is ongoing, with perennial species targeted because of their invasiveness and competitive ability. Perennial veldt grass (*Ehrharta calycina*), pigface (*Carpobrotus edulis)* and couch (*Cynodon dactylon*) were sprayed using herbicides from 2012 to 2017. There was a substantial increase in weed cover due to disrupted funding in 2015 that limited the activities at the sites, but most areas were sprayed again in 2016. Other invasive weeds (all bulbs, *Euphorbia, Pelargonium*, *Carpobrotus*, *Lupinus,* etc.) were removed by hand each year including 2017. It is anticipated that several more years of weed control will be sufficient to control major weeds at these sites. See Section 6 for further details about weed management methods and outcomes.

Table 4. Total areas that received topsoil, seed or plants by year (planting occurred in all areas).

Restoration activity	Timing	Anketell Rd (ha)	Forrestdale Lake (ha)	Total (ha)
Topsoil transfer	2012	11.5	4.5	16
Planting	2012	2.5	1.5	4
	2013	9	7	16
	2014	32	7.5	39.5
	2015	26	3	29
	TOTAL	32	7.5	39.5
Direct seeding	2012	2	0.5	2.5
	2013	10	-	10
	2014	12	-	12
	2016	12.5	1	13.5
	TOTAL	15.5	1	16.5
Fencing	TOTAL	23	3.5	26.5
Total for all activities		**39**	**11**	**50**

3.3 Direct Seeding and Hand Seeding

In some areas of the restoration sites, topsoil transfer was not an option because topsoil from Jandakot Airport was not available at suitable times, in sufficient quantities, or because vegetation types of the topsoil source areas did not suit the soil conditions of potential recipient locations. In these cases, direct seeding was the most efficient option for revegetating large areas with few pre-existing native plants. In 2012-2016, a total of 16.5 ha at Anketell Road and Forrestdale Lake were direct seeded by Greening Australia WA using machinery. Seeds were mixed with wetting agent, fertiliser and bulking agents (sand and vermiculite), and applied using seed drill technology (see Fig. 5A).

To infill smaller areas, a hand direct seeding method was developed for use in 2016 using seed mixed with bulking agents as described above. This was carried out by DBCA staff and volunteers by digging a shallow furrow with a hoe and then funnelling the seed mix through a 1 m plastic pipe while walking down the rows (Fig. 5C). The seeds were then covered with a thin layer of soil. In total, more than 30 kg of seed (excluding seeds of the cycad *Macrozamia*) was used for direct seeding Anketell Road and Forrestdale Lake over 2012-2016 (Table 2).

In general, direct seeding by machine was successful at restoring a moderate diversity of banksia woodland plants (Fig. 5B), but plant diversity and density was substantially lower in areas without respread topsoil (see Section 4.6). Several years of planting and seeding were required in each area because of high summer attrition. Results of seeding were often uneven, with some areas of very dense seedlings (see Fig. 5D) and other areas where seedlings were widely spaced. However, we were able to fill in large gaps by a second application of seed in 2016 using machine direct seeding or hand seeding in open areas. It was possible to drive around established plants to avoid damaging them when reseeding large areas.

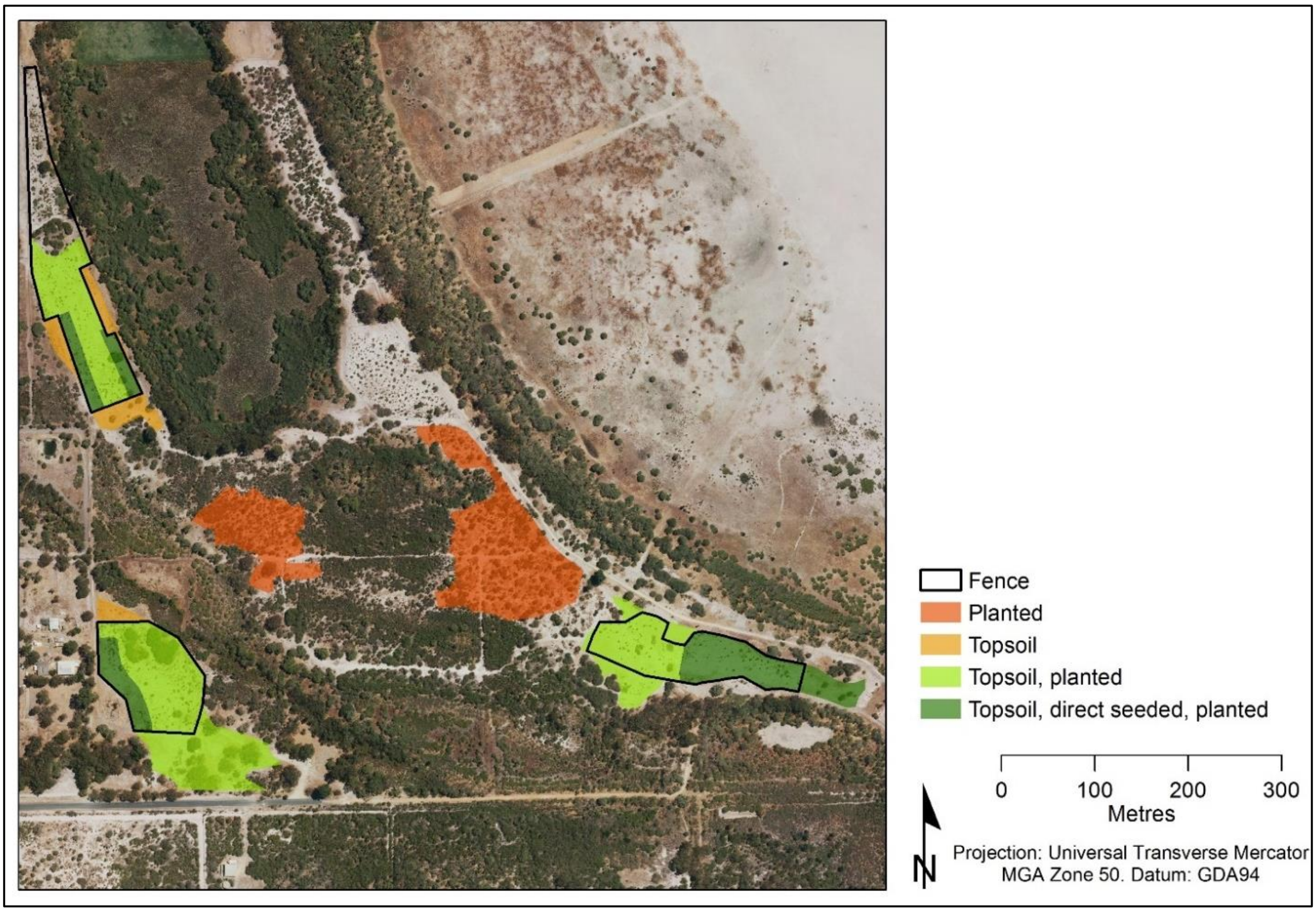


Figure 3. Forrestdale Lake restoration site showing total areas fenced, direct seeded and planted from 2012 to 2016.

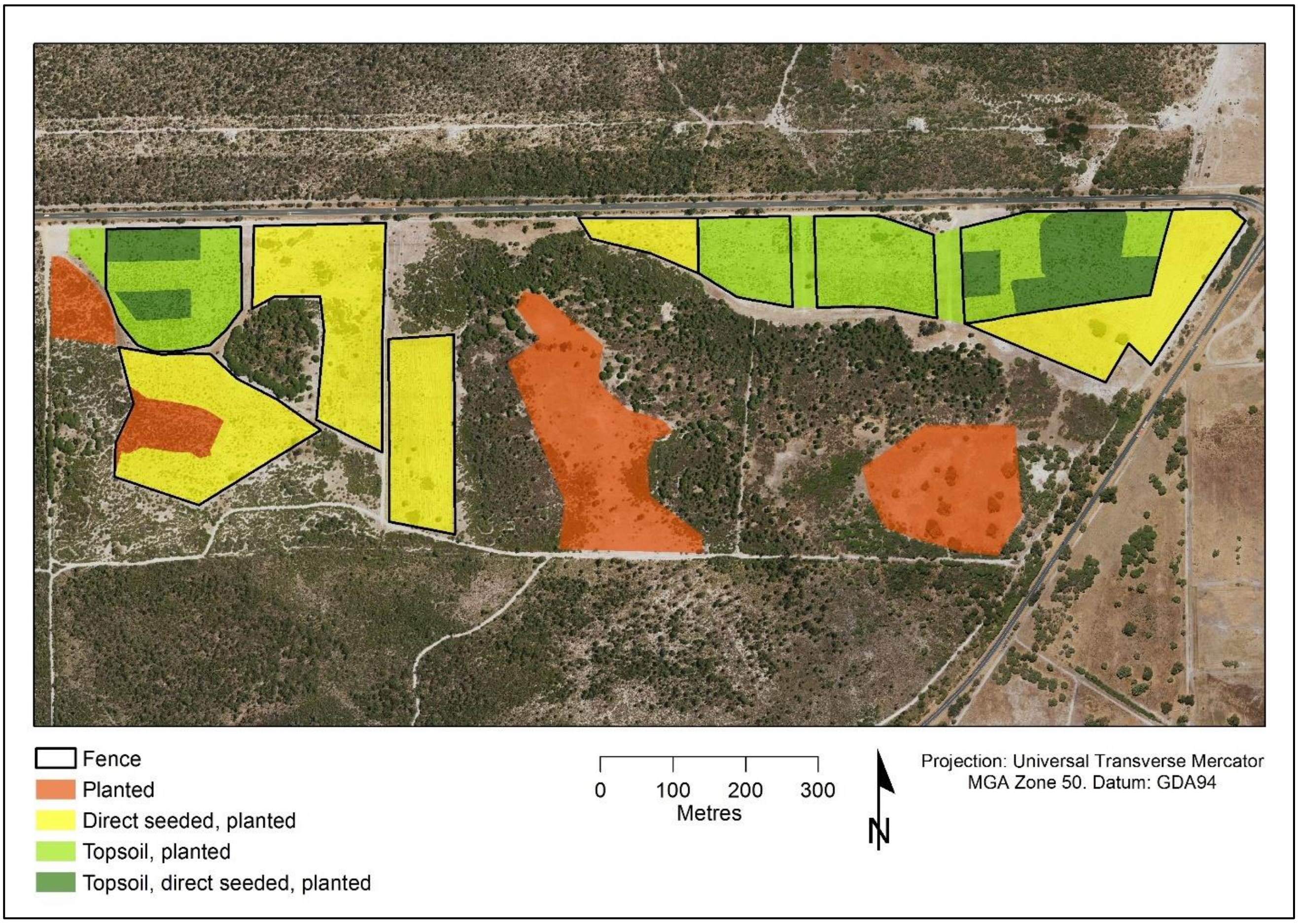


Figure 4. Anketell Road restoration site showing total areas fenced, direct seeded and planted from 2012 to 2016.

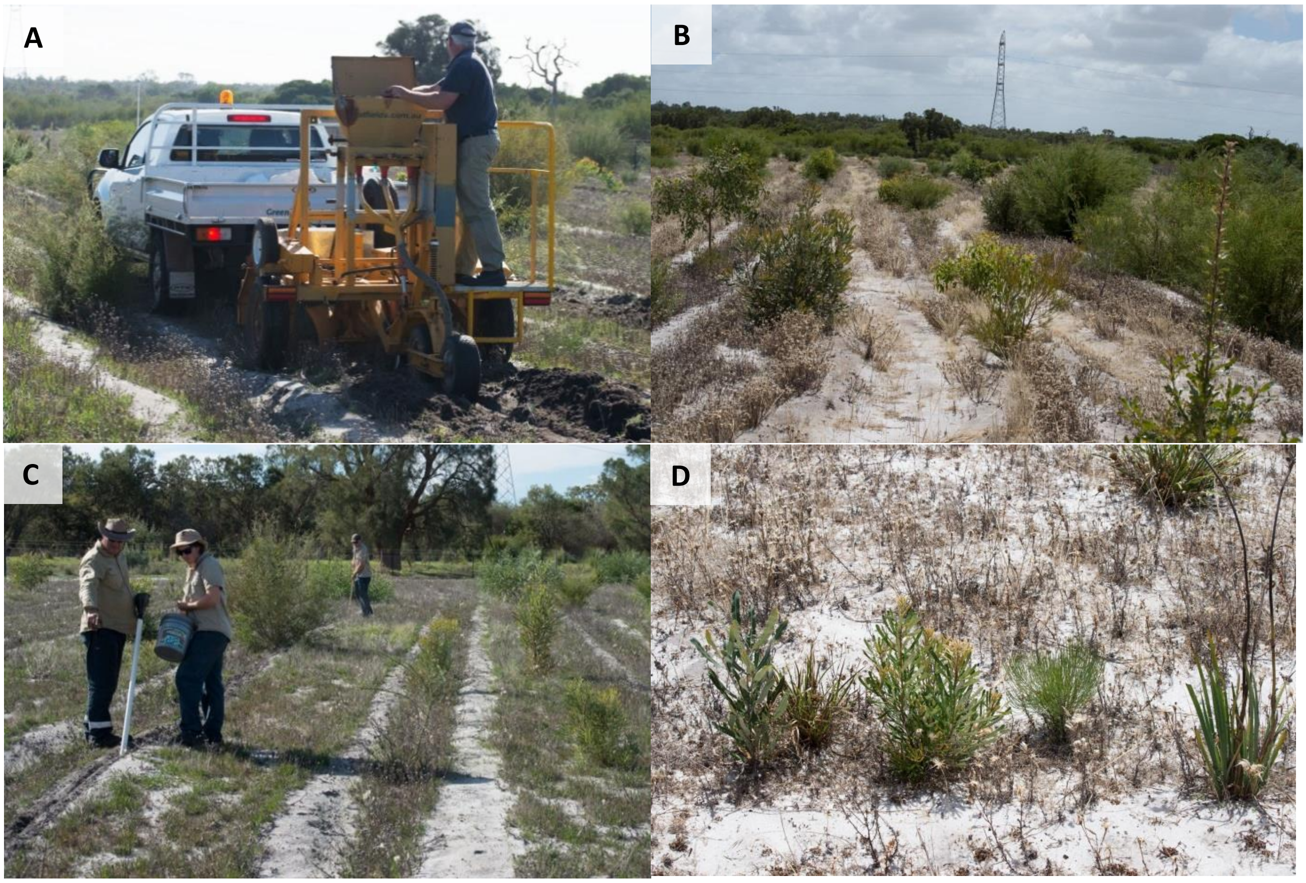


Figure 5. A. Direct seeding undertaken by Greening Australia WA using a seed drill in 2016 at Anketell Road. **B.** The same area with the newly seeded rows in 2017. **C.** Hand direct-seeding with the help of DBCA Regional Parks staff in late May 2016. **D.** Example showing dense germination resulting from hand direct seeding (left to right: *Banksia menziesii, Conostylis aculeata, Banksia attenuata, Persoonia saccata, Anigozanthos manglesii*).

4. Monitoring Survival and Recruitment in Restoration Areas

Monitoring of restoration areas for comparison with the completion criteria targets (shown in Table 6) required a combination of four different methods. From 2012-2016, cover and density of all species were measured within 1x1 m quadrats arranged along transects, since it was impractical to quantify annual plants and seedlings on a larger scale. From 2014-2017, 5x5 m quadrats were used to monitor plant density and foliage cover of perennial natives and weeds, as well as cover of annuals. In total, 144 of these quadrats have been established: from 2014-2016, 80 quadrats were used to monitor areas at Anketell Road and Forrestdale Lake restored with topsoil, and in 2017 an additional 64 quadrats were used to monitor areas of Anketell Road without topsoil that were restored using direct seeding and planting. The 5x5 m quadrats are analysed in groups of four to create virtual 10x10 m quadrats for comparison with reference sites. To establish species-area relationships, plant diversity was measured in a series of nested quadrats ranging in size from 5x5 m to 50x50 m at Anketell Road. Twenty-eight 25x25 m quadrats are used to measure tree density, flowering and seed production. Photo monitoring points have also been established in all restoration areas (Figs. 6, 7).

Figure 6. Examples of photo monitoring from the restoration sites showing annual increments in vegetation cover. **A.** This example shows annual changes in an area of Anketell Road from April 2013 (after topsoil transfer and prior to planting) to March 2017. **B.** This time sequence shows an area at Forrestdale Lake before topsoil transfer (February 2012), until March 2017. The impact of grazing on vegetation can be clearly seen outside the fenced area (left side of images).

4.1 Rainfall and Climate

Plant survival and growth during the first five years of restoration at the Anketell Road and Forrestdale Lake sites were seriously impacted by periods of severe drought in autumn, winter and/or late spring in most years of the project (Fig. 7). A rapid decline in spring rainfall substantially increased the mortality of seedlings and planted tubestock at the restoration sites in 2012, 2013 and 2015. Total rainfall for 2017 was slightly above average (862 mm), but the rainfall pattern was unusual with abnormally high rainfall in late summer (February) and a drier than normal autumn. As in other years there was a rapid decline in rainfall in late spring that had a major impact on germination and seedling survival (Fig. 7).

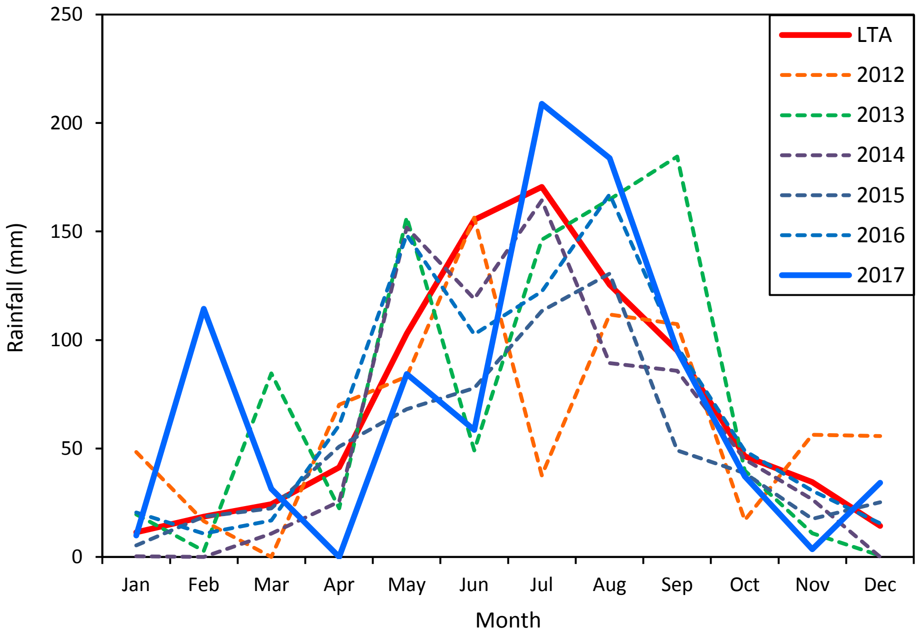


Figure 7. Monthly rainfall (mm) at the Anketell Road weather station over the period 2012 to 2017 (bom.gov.au). The long-term average (LTA) is the mean from 1985 onwards.

Mean annual rainfall for 1985-2017 is 840.7 mm.

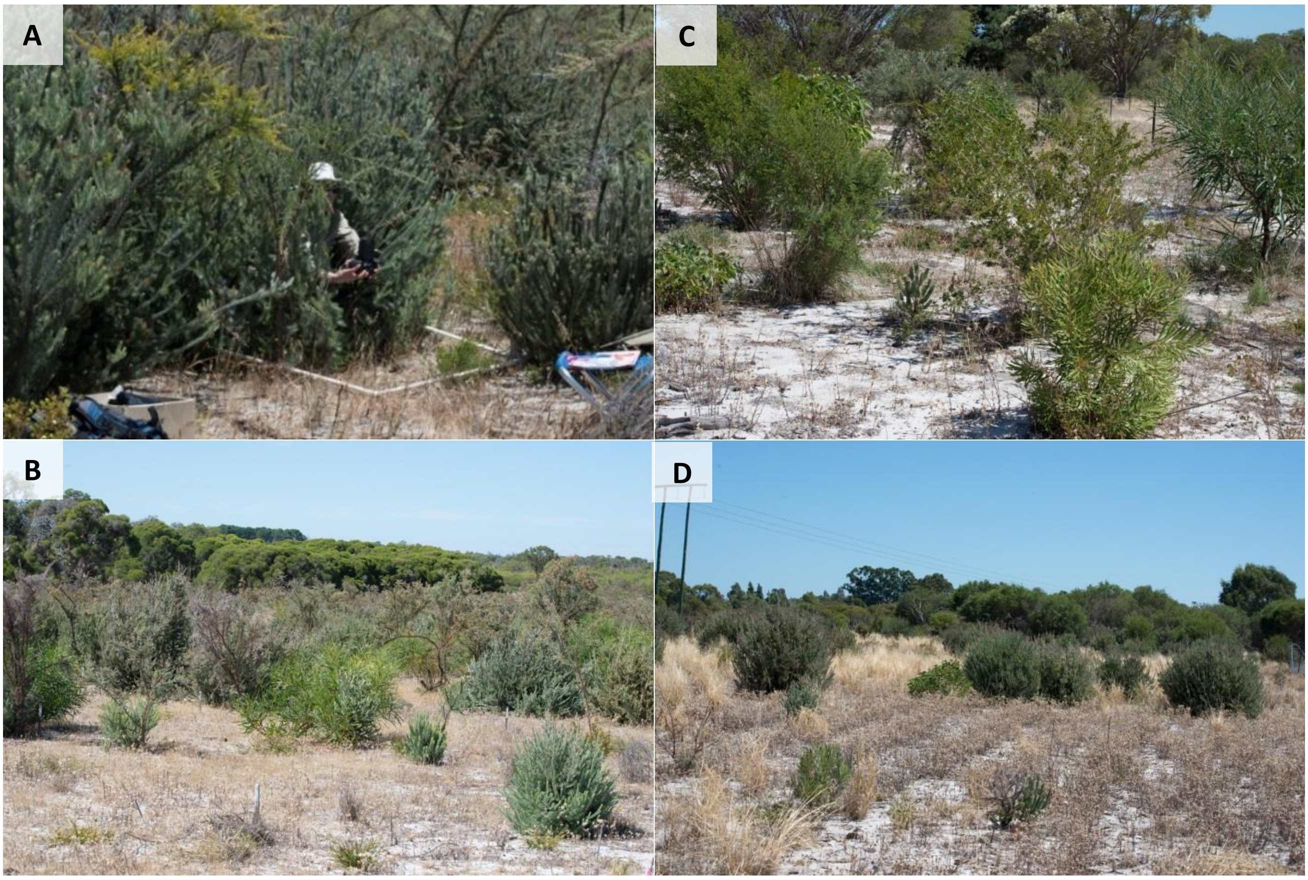


Figure 8. A. Taking monitoring photos in dense vegetation on the Anketell Road restoration site. **B.** Anketell Road transition area with low survival in foreground and dense natives in background. **C.** Forrestdale Lake area with higher seedling survival. **D.** Forrestdale Lake area with low seedling survival.

4.2. Plant Cover

Five years after restoration began, foliage cover is continuing to increase (Figs. 6AB), though cover is patchy with dense areas (Figs. 8AC) and some sparsely vegetated areas (Figs. 8CD). Percentage foliage cover was estimated in 5x5 m quadrats in areas restored with topsoil (surveyed over 2014-2017) and in younger restoration areas without topsoil (surveyed in 2017 only).

Foliage cover of perennial native species has increased steadily at both sites (Fig. 9), although by autumn 2017 there was twice as much cover at Anketell Road (21%) compared to Forrestdale Lake (12%). As expected, areas restored without topsoil at Anketell Road had a lower cover of natives (8%), because restoration works began two years later and consisted of direct seeding and planting only. In autumn 2017, weed cover was around 6% at Anketell Road (in both areas with and without topsoil), while Forrestdale Lake had lower perennial weed cover (4%). Perennial weed cover at both sites has fluctuated with management and rainfall. Ongoing control is likely to be needed to ensure they do not regain dominance, especially in direct seeded areas (Fig. 9).

At both sites shrubs dominate the foliage cover, with 17% cover in spring 2017 at Anketell Road topsoil areas. Trees were the next highest category at just over 2% cover, while herbs, sedges and grasses together made up only 1% cover (Fig. 10). Cover of all categories is steadily increasing over time, with slower growth (and sometimes a slight decline) in cover over winter, while the increase in foliage cover is evident over the summer growth period (Fig. 10). Vegetation structure differs somewhat at Forrestdale Lake, which has proportionally higher cover of shrubs, and lower cover of trees, sedges, grasses and herbs. Anketell Road areas without topsoil have a higher proportion of tree cover (see Section 4.6).

At the Anketell Road topsoil areas, several perennial weed species (*Gladiolus caryophyllaceus, Ehrharta calycina, Romulea rosea*) were widespread and occurred in more than 50% of quadrats, but all weed species had less than 1% foliage cover in spring 2017 (Fig. 11). Couch grass (*Cynodon dactylon*) had the highest cover at just over 0.6%. In areas of Anketell Road without topsoil (direct seeded areas), the frequency of individual perennial weed species was lower (Fig. 12). Perennial veldt grass was the most widespread, occurring in 40% of quadrats. Couch grass was also a major issue in these areas, occurring in nearly 20% of quadrats, and had much higher cover compared to areas with topsoil (5% compared to 0.6%).

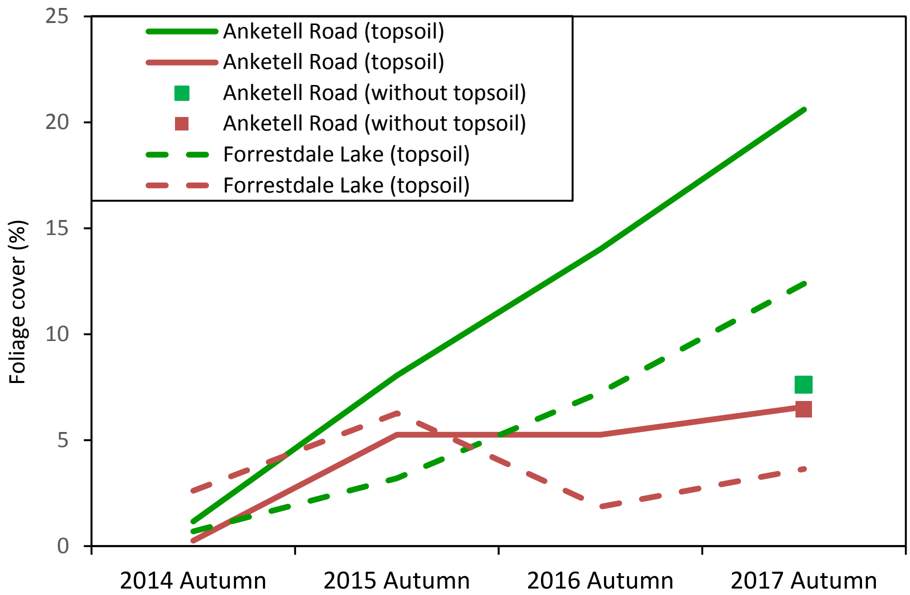


Figure 9. Changes in foliage cover for perennial weeds (red) and native plants (green) at Anketell Road and Forrestdale Lake. Results show cover in the 5x5 m quadrats (topsoil areas only) over 2014-2017. Areas without topsoil were only monitored in 2017 (squares on graph). Cover is displayed for autumn only so does not show spring peaks for annuals.

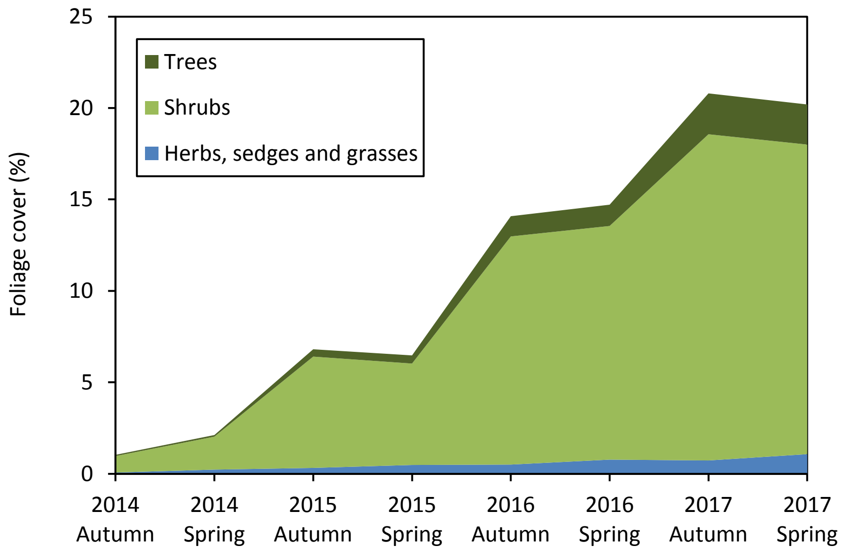


Figure 10. Foliage cover of native perennials grouped by growth form at the Anketell Road restoration site (topsoil areas only). Foliage cover is dominated by understory shrubs with nearly 17% cover by spring 2017, while trees were at 2% cover and herbs, shrubs and grasses at 1%.

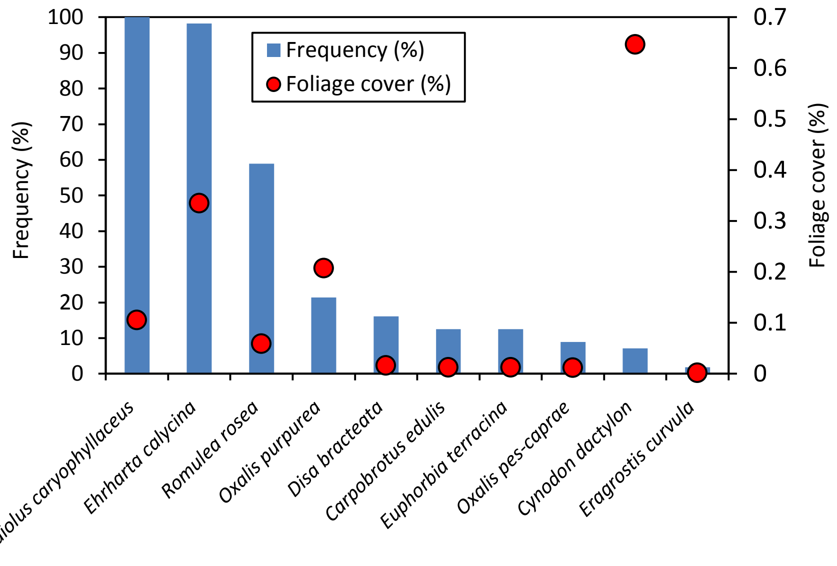


Figure 11. Frequency and foliage cover of perennial weeds at Anketell Road topsoil areas in spring 2017. Some weeds were widespread, but all had low average cover (<1%). These data are from 5x5 m quadrats (n = 56). Red dots show total cover (scale on right).

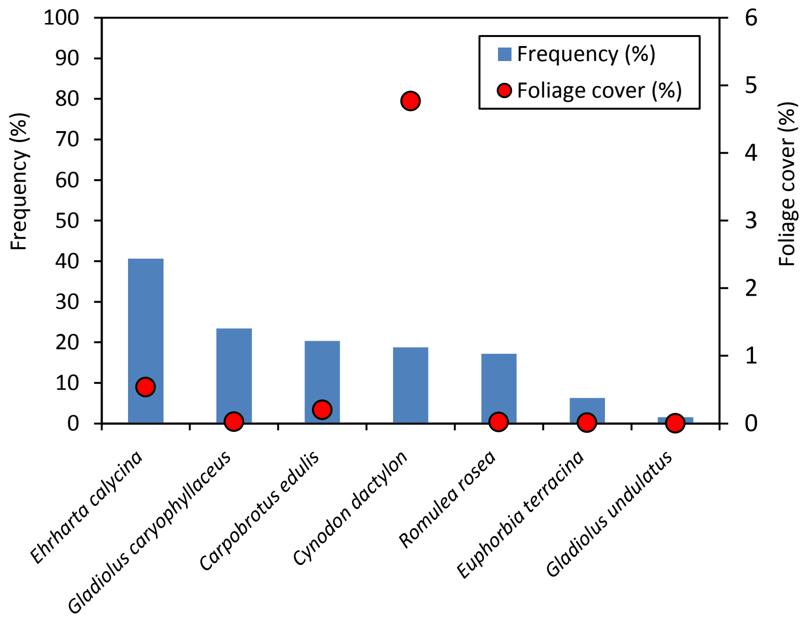


Figure 12. Frequency and cover of perennial weeds at Anketell Road areas restored without topsoil in spring 2017. Weed species occurred less frequently than in topsoil areas, but couch had much higher cover (around 5%). These data are from 5x5 m quadrats (n = 64). Red dots show total cover (scale on right).

4.3. Plant Density

Most perennial native plants on the restoration sites originate from germination from the topsoil seed bank. These include many shrubs and herbs as well as geophytes, which grew from seed, tubers or roots transferred in topsoil (Appendix 2). At Anketell Road, perennial native plant density peaked at over 125,000 stems per ha as measured in the 1x1 m survey in spring 2013. Forrestdale Lake peaked at nearly 100,000 stems per ha in spring 2012. However, despite the large number of seedlings that germinated, many seedlings did not survive the severe spring and summer droughts that occurred most years of the project (Figs. 13, 14).

In the Anketell Road topsoil areas, the target density of 7,000 stems per ha was reached by autumn 2015 (Fig. 13). Despite declines in density over summer 2015/16 and 2016/17, the perennial native density has continued to increase each year. By spring 2017, there were nearly 43,000 stems per ha of perennial natives including seedlings (20,000 stems per ha excluding seedlings), far exceeding the density target of 7,000 stems per ha (Fig. 13). In contrast, density at Forrestdale Lake reached the target in autumn 2015 but declined in 2016. Native plant density is just below target at 6,950 stems per ha excluding seedlings as of spring 2017, and just over target at 7,750 stems per ha if seedlings are included (Fig. 13). Many seedlings perished each summer, but new seedlings germinated each winter. Native plant density in areas of Anketell Road restored without topsoil is at nearly 6,000 stems per ha including seedlings, and 3,300 stems per ha without (Fig. 13). Areas restored without topsoil are not expected to reach the same native plant density as areas restored with topsoil, therefore the completion criteria target of 7,000 stems per ha does not apply to these areas (see Section 4.8).

Perennial weed density has increased annually since 2014 and fluctuates seasonally more than the perennial native plants (Fig. 14). This fluctuation is due to the presence of several tuberous and cormous geophytes, including wild gladiolus (*Gladiolus caryophyllaceus*), soursob (*Oxalis pes-caprae*), largeflower wood sorrel (*O. purpurea*), and Guildford grass (*Romulea rosea*). These plants are numerous and increasing in number, but as they are small, annually renewing plants, the threat of competition with native plants is not great and they are not a priority for management. Cape weed (*Arctotheca calendula*), which is the commonest annual weed, has become less dominant, perhaps due to parasitism by broomrape (*Orobanche minor*) plants (Section 4.9).

Tree density, measured using 25x25 m quadrats on the Anketell Road site, had reached the 300 stems per ha target in the topsoil areas by 2014 (Fig. 14). However, tree density later dropped below target, falling to 243 stems per ha in 2017. Tree density is further below target at Forrestdale Lake (183 stems per ha), where density could only be measured using 5x5 m quadrats as the small site did not have space for 25x25 m quadrats. At Anketell Road areas restored without topsoil (direct seeded and planted), tree density reached the target, with a density of 362 stems per ha in 2017, measured in 25x25m quadrats. These areas were largely in lower-lying areas of the site and historically transitional dampland, which may explain why survival in these areas was better compared to more upland areas (see also Section 4.6).

There are several sections within restored areas of Anketell Road and Forrestdale Lake that have much lower native plant density and may require additional infill planting or seeding in future years (see Section 4.7). However, most native plants present have flowered and sets seed and second-generation seedlings of some species are fairly common (see Section 4.9). Thus, it will be necessary to monitor future recruitment within sites to determine if additional infill planting or seeding is required, or if natural recruitment process will be sufficient to infill areas with low plant density.

Additional monitoring results were provided by Murdoch University PhD student Pawel Waryszak, who measured recruitment from topsoil-stored seed from 2012 to 2014. Pawel's thesis was funded by this project and completed in late 2016. He measured abundant recruitment of native plants from topsoil, but confirmed that mortality of seedlings over summer was extremely high and treatments to promote germination or seedling survival, such as increased topsoil depth, had little impact (Waryszak 2016). His thesis has been published and papers resulting from his work are currently in the process of being written.

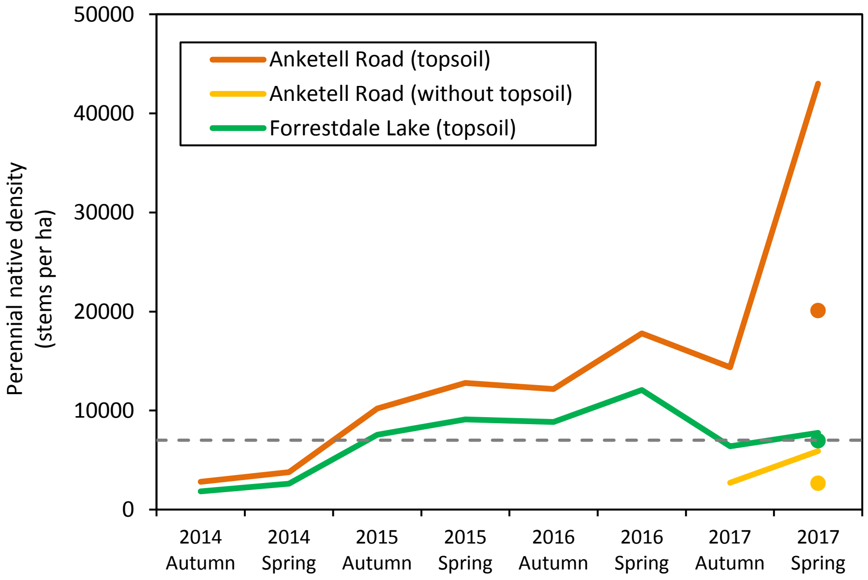


Figure 13. Perennial native density for biannual surveys of 5x5 m quadrats from 2014-2017. The completion criteria target of 7,000 stems per ha is shown by the dashed line. Dots in 2017 show density excluding seedlings for comparison. Topsoil areas at Anketell Road are exceeding the target while Forrestdale Lake is just below target (without seedlings). Seedlings were not counted in the 2014 surveys.

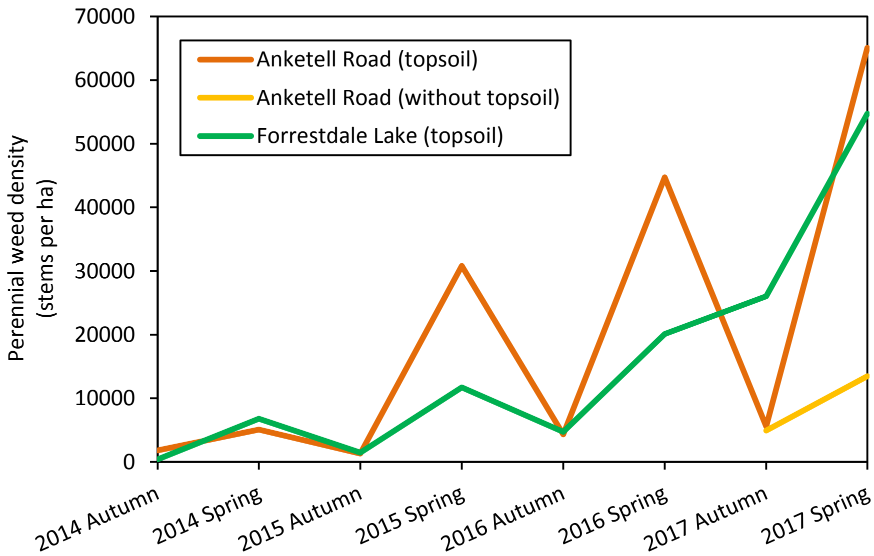


Figure 14. Perennial weed density (stems per ha) from biannual surveys from 2014-2017. Perennial weed density fluctuates seasonally more than the native plants, because they include several tuberous and cormous geophytes e.g. *Gladiolus caryophyllaceus* and *Oxalis purpurea*.

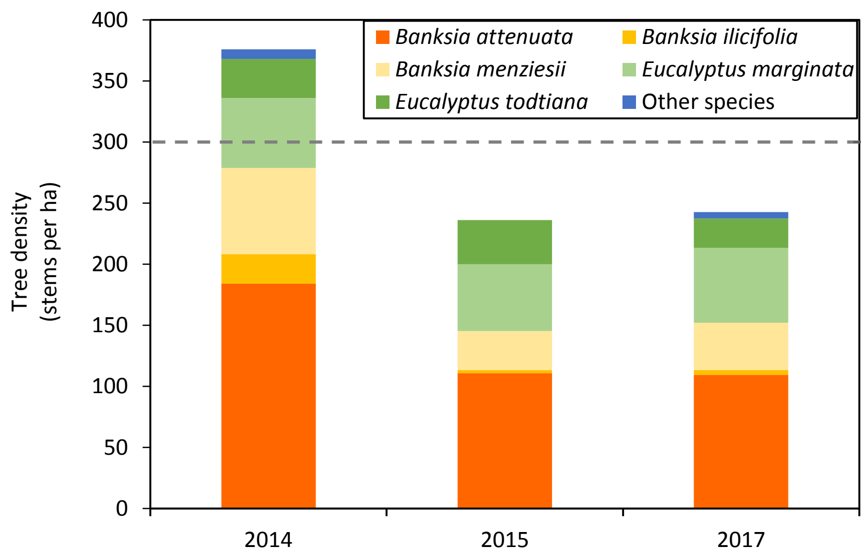


Figure 15. Tree density (stems per ha) from surveys of 25x25 m quadrats at Anketell Road (topsoil areas). Tree density was above the 300 stems per ha target (dashed line) in 2014, but since then has dropped below target, presumably due to drought deaths during exceptionally dry summers.

4.4. Plant Diversity

After five years, the total diversity of native plants at both Anketell Road and Forrestdale Lake is similar to that found in reference sites, with about 162 native plants found at both sites (Appendix 2). The diversity of plants in 10x10 m equivalent quadrats have reached targets based on reference quadrats after five years (Table 5). The majority of native species found in Jandakot Airport reference quadrats have either germinated from topsoil or were planted or seeded on the restoration sites. However, some key differences were also noted, including 22 native plant species observed in restoration sites, but not in surveys of the topsoil harvest area. These include local opportunists that have spread from adjacent areas (Fig. 16), but most are disturbance opportunists (i.e. short-lived plants that germinate after soil disturbances or fire). The most common plants derived from respread topsoil include annual species of *Austrostipa, Podotheca* and *Trachymene* and small shrubs such as *Gastrolobium capitatum* and *Gompholobium tomentosum*. These plants were initially very abundant, but their numbers declined somewhat by the third year. Larger shrubs that are also very common in restored areas include *Adenanthos cygnorum* and *Jacksonia furcellata* (Fig. 6). These disturbance opportunists have key roles during vegetation establishment, but often senesce within a few decades, persisting as seed in the soil seed bank until the next disturbance. There are also a few common native species from references sites, such as *Conostephium* spp., that are rare or absent in restored areas. There are close to 100 species of weeds present in the restoration areas, the majority of which are of limited concern because they are small shade-intolerant annuals that are expected to diminish in importance over time as total foliage cover increases. Perennial weeds of greater concern are discussed in Section 4.2.

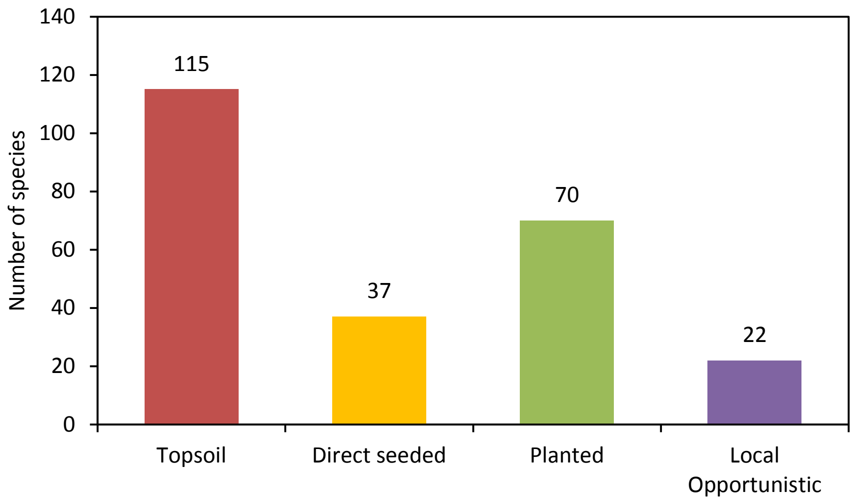


Figure 16. Comparison of the number of native plant species recruited from different propagule sources. There is some overlap between categories, especially for planted and direct seeded species.

In total, 162 species have been identified in the restoration areas. A complete species list is provided in Appendix 2.

4.5. Tree Survival and Growth

Measurements of tree height showed differences in growth rates between species (Fig. 17); eucalypt trees showed the fastest growth, increasing in height by an average of 58 cm per year, while *Banksia attenuata* grew an average of 50 cm per year. B*anksia menziesii* had the slowest growth at 36 cm per year, but this may be due to earlier flowering than other trees. The oldest trees were seeded or planted in 2012, so were five years old and between 1-2.5 m tall in spring 2017 (Fig. 17). However, some trees are much taller than this, with a few that are about 5 m tall, as shown for *Eucalyptus rudis* in Figure 18A.

A study of banksia tree growth, health and seed production was undertaken by students from The University of Western Australia (UWA) in spring 2017 (Fig. 18B). Tree height, canopy volume and follicle production were measured, and stress scored on a four-point scale. Variation of canopy volume (m^3) with basal stem diameter (at 10 cm height) for juvenile *Banksia attenuata* and *B. menziesii* measured in three 50x50 m quadrats at the Anketell Road restoration site is shown in Figure 19. Plants were aged between two and five years old resulting from seedlings planted from 2012 to 2015 and seed sown in 2012. At this stage one-third of *B. menziesii* trees had flowered, but only one *B. attenuata* had flowered. The first seed set and recruitment of seedlings from trees on the site were found in 2016 (e.g. Fig. 24A). This teaching exercise was repeated in May 2018.

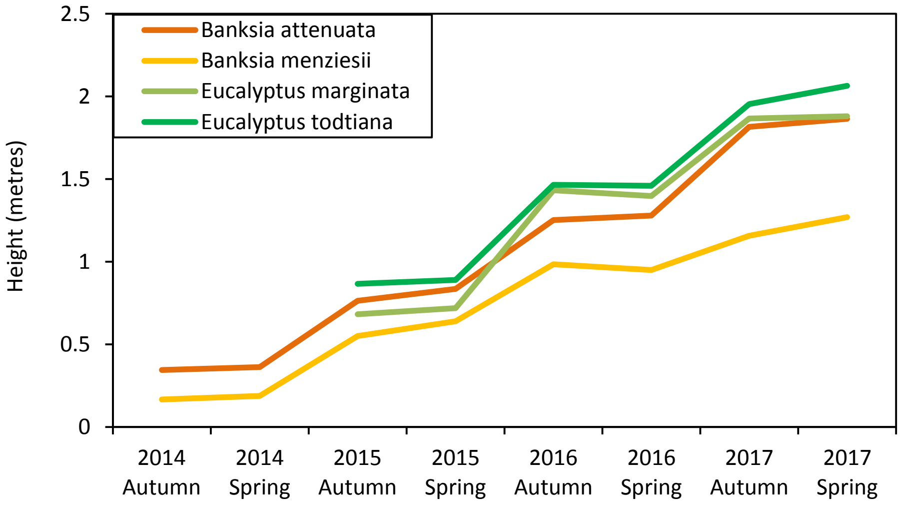


Figure 17. Average growth of the four most common tree species at Anketell Road topsoil areas from 2014-2017 (2012/2013 cohort). By spring 2017, at four or five years old, *Eucalyptus todtiana* trees averaged just over 2 m tall, while *Banksia menziesii* was, on average, the shortest species at 1.3 m. Note that tree growth occurs primarily in summer. Eucalypt trees were not measured in the 2014 surveys.

Figure 18. A. One of the tallest eucalypts from five-year-old direct seeding at Anketell Road. This *Eucalyptus rudis* stands at 4.7 m tall but has not yet flowered and set seed.

B. Biological science students from The University of Western Australia measuring a young *Banksia menziesii* plant in Anketell Road as part of an exercise to examine health and growth of *Banksia* spp. Results for canopy volume are presented in Fig. 19.

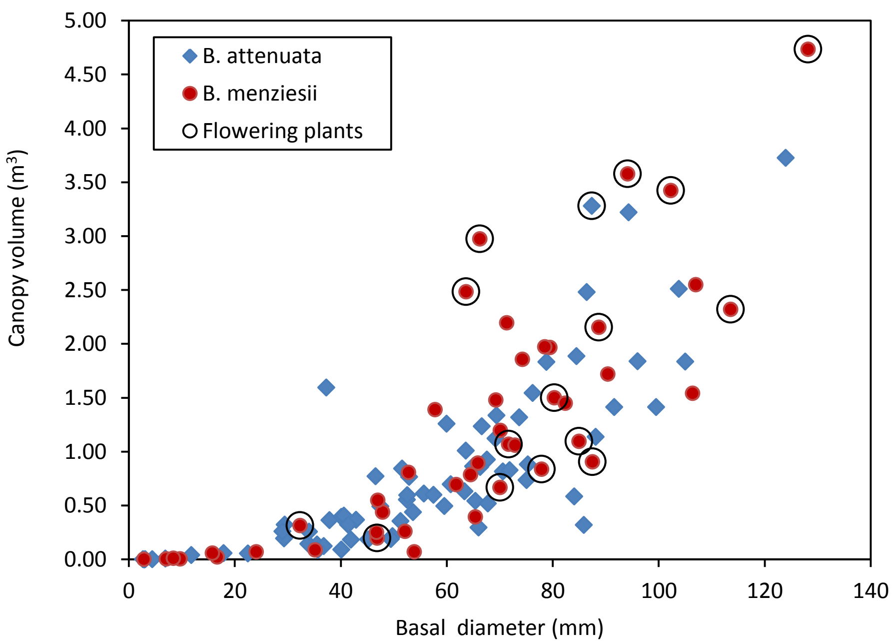


Figure 19. Variation of canopy volume (m^3) with basal stem diameter (at 10 cm height) for juvenile *Banksia attenuata* and *B. menziesii* measured in three 50x50 m quadrats at the Anketell Road restoration site. Circled markers indicate plants that have flowered. These data were the result of a training exercise for students, as explained above (Fig. 18B).

4.6. Comparison of Methods

Data from restoration monitoring at Anketell Road were used to compare results from areas that received transferred topsoil in 2012 (11.5 ha), with those that were restored by direct seeding and planting only from 2014 onwards (13.3 ha). Table 5 summarises results from spring 2017 surveys of 5x5 m and 25x25 m quadrats. Topsoil areas had higher perennial native density of 43,000 stems per ha, compared to 6,000 stems per ha in non-topsoil areas. Areas without topsoil were not expected to reach the same plant density as areas restored with topsoil, so had less stringent completion criteria targets (see Section 4.8). Perennial weed density was at 65,000 stems per ha in topsoil areas, and much lower in areas without topsoil (13,500 stems per ha). These large numbers were primarily due to the bulbous weed *Oxalis purpurea* in topsoil areas (40,000 stems per ha) and perennial veldt grass (*Ehrharta calycina*) in both areas (13,000 stems per ha). Tree density was highest in areas without topsoil (362 stems per ha) compared to areas with topsoil (243 stems per ha). This is likely because most areas without topsoil tended to be lower-lying, transitional dampland areas relative to the topsoil areas that are located a few metres further upslope.

As expected, native species richness was higher in topsoil areas, with 96 perennial and 18 annual species in spring 2017. In comparison, areas without topsoil had 61 perennial and 10 annual native species. Lower native species richness was expected in areas without topsoil, due to the absence of species that are difficult or impossible to return by direct seeding or planting. The difference in species richness is most noticeable in the understory. Non-topsoil areas had roughly half the number of species in the combined category of grasses, sedges and herbs and two-thirds the number of shrub species compared to topsoil areas.

Perennial native foliage cover was lower in non-topsoil areas (8%) compared to topsoil areas (20%) where restoration began two years earlier. However, there was higher foliage cover of annual natives in the areas without topsoil, probably due to less understory competition. Overall weed cover was higher in areas without topsoil (11%) compared to topsoil areas (5%). This difference in weed cover was mainly due to couch (*Cynodon dactylon*), which makes up most of the perennial weed cover in areas without topsoil. Couch grass has been sprayed several times, but continued management is expected to be required to control it across the site until there is sufficient shade by native plants.

Tree species richness was higher in the non-topsoil areas, with 10 tree species returned to the non-topsoil areas compared to seven in the topsoil areas. A higher diversity of trees including *Melaleuca* species were planted and seeded in dampland areas without topsoil, some of which would not have been suitable for the upland areas with respread topsoil. The number of weed species present was similar for both areas.

Table 5. Spring 2017 restoration results in Anketell Road topsoil areas compared to areas that did not receive topsoil. In topsoil areas, restoration began in 2012 with a topsoil transfer and was followed up with planting and direct seeding, while in areas without topsoil restoration began in 2014 and only direct seeding and planting were used.

Measurement		Survey type	Topsoil (restoration began in 2012)	No topsoil (restoration began in 2014)
Density (stems per ha)	Perennial natives	5x5 m	42,986	5,931
	Perennial weeds	5x5 m	65,057	13,475
	Trees	25x25 m	243	362
Species richness (number of species)	Perennial natives	5x5 m & 25x25 m	96	61
	Annual natives	5x5 m & 25x25 m	18	10
	Perennial weeds	5x5 m & 25x25 m	11	9
	Annual weeds	5x5 m & 25x25 m	25	29
Species composition (number of species)	Grasses, sedges and herbs	5x5 m & 25x25 m	63	32
	Shrubs	5x5 m & 25x25 m	44	29
	Trees	5x5 m & 25x25 m	7	10
Foliage cover (%)	Perennial natives	5x5 m	20	8
	Annual natives	5x5 m	4	10
	Perennial weeds	5x5 m	1	5
	Annual weeds	5x5 m	4	6

4.7. Spatial Variability in Restoration Sites

Figure 20 shows the change over time in the percentage of quadrats reaching the target 7,000 stems per ha for perennial native plant density. As of 2017 spring, at Anketell Road 70% of quadrats reached the target, while at Forrestdale Lake only 38% of quadrats were at target density and in recent years there has been a downward trend (Fig. 20). Some areas at Forrestdale Lake had buildings, tracks and gardens that were removed after the land was purchased for conservation, which likely resulted in problems with soil structure or chemistry. Additionally, the Forrestdale Lake site has a partial canopy of established trees that would compete strongly for water and other resources, especially in summer. Example photos of areas with good and poor vegetation establishment at both sites are shown in Figure 7.

Figure 21A shows how native perennial plant density varies across Anketell Road. In areas that received topsoil, native perennial plant density has reached the target of 7,000 stems per ha in many areas (green squares in Fig. 21A), but other areas have not yet reached this target (yellow, orange and red squares in Fig. 21A). Of the topsoil areas, the eastern-most end of the site has the poorest results with half of quadrats in that fenced area not reaching target (Fig. 21). Reasons for this have not been confirmed, but may be due to water availability, weed completion, or soil compaction. As expected, native plant densities are much lower in areas without topsoil, with most quadrats not reaching the target used for topsoil areas.

Monitoring of four unfenced 5x5 m control quadrats showed that fencing to exclude rabbits and kangaroos was essential for the restoration's success (yellow arrow in Fig. 21A). This area had been machine direct-seeded in 2013, but as of spring 2017 there are no perennial native plants present in this unfenced area, except for the pre-existing weedy native *Kunzea glabrescens*. We have recently observed increased evidence of kangaroo activity within fenced areas (scats and grazing), due to breaches in the fencing and because the plastic sight lines used to deter them have become less effective over time. However, the fences we used provided adequate protection during the establishment of vegetation.

Visualisation of restoration outcomes by overlaying quadrat results onto aerial photography (e.g. Figure 21) is more helpful for restoration site management compared with only looking at averages taken across a site. Spatial approaches enable targeted management such as infill planting for areas where outcomes have been poorer and can identify issues with the site showing common factors for areas with better or poorer results (e.g. Fig. 20). For example, areas with better results tended to be lower in the landscape, and areas with poorer results occurred in unfenced areas or on compacted soil such as along old tracks.

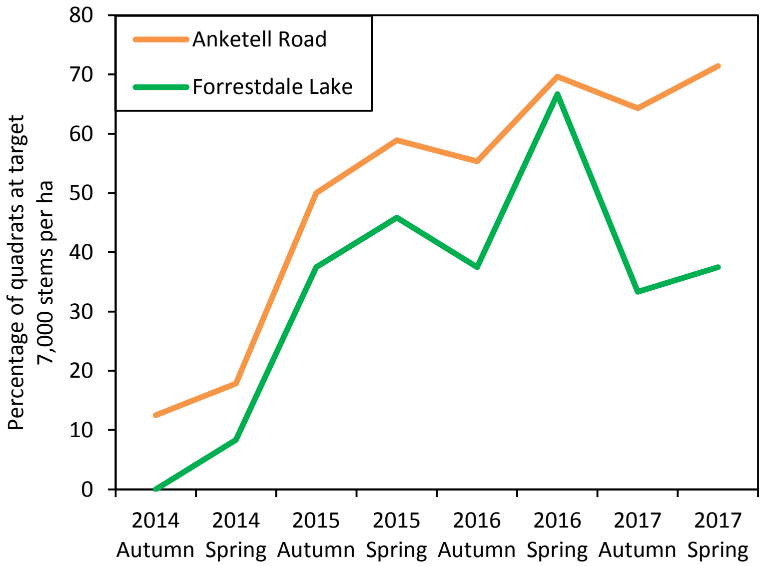


Figure 20. The change over time in the percentage of monitoring quadrats reaching target density for perennial natives (7,000 stems per ha) at Anketell Road and Forrestdale Lake (areas restored with topsoil only). The increase in quadrats reaching target is due to topsoil transfer, planting and direct seeding from 2012-2016. Data are from 5x5 m quadrats (n = 56).

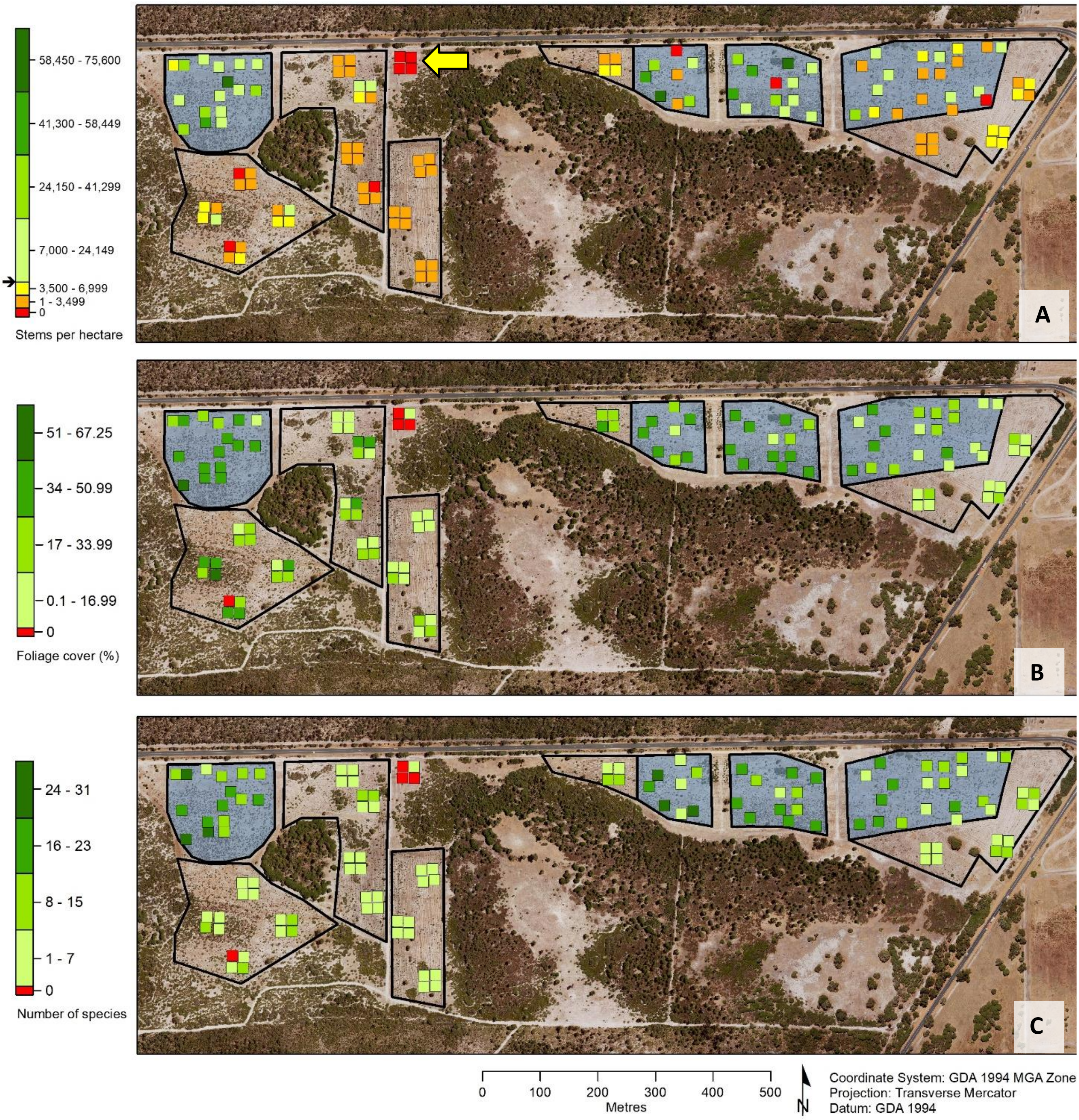


Figure 21. Spring 2017 results for native perennial plants from 5x5 m quadrats plotted over an aerial photo. Blue-shaded areas show areas restored with topsoil. Black outlines show fencing. The control area without fencing or planting is indicated by yellow arrow in A. Quadrats are not drawn to scale. **A.** Variations in native perennial plant density. All green-shaded quadrats are above the target density of 7,000 stems per ha as indicated on the colour scale with a black arrow. This completion criteria target only applies to areas restored using topsoil, with non-topsoil areas included for comparison. **B.** Foliage cover of native perennials. Four quadrats shown in red contained zero foliage cover, while quadrats shaded green show the level of cover with darker green indicating higher cover. **C.** Number of perennial native species per quadrat. Four quadrats with no perennial native species are shaded red, while quadrats shaded green contained at least one perennial native species (darker green categories indicate greater species richness).

4.8. Restoration Outcomes Relative to Targets

After five years, most diversity targets have been reached, but seed germination from the topsoil was highly variable so there are some areas with low native cover (see Fig. 8). As illustrated in Figure 16, the topsoil seed bank provides about half of the species present, though it does not provide trees and a few large shrubs with canopy-stored seed, so these species were added by direct seeding and planting. Overall targets for native perennial plant density have been reached at Anketell Road (Table 6), although additional planting or seeding may be required to reach targets for tree density and Carnaby's cockatoo food plants. However, the future potential for these trees to spread within sites needs to be measured because they have begun to flower and set seed. The same restoration methods at Forrestdale Lake resulted in lower density of perennial natives and trees, as both were short of targets in spring 2017 (Table 6). This is likely due to summer drought deaths in combination with historical land uses that affected soil properties.

In areas of Anketell Road restored without respread topsoil, tree density has exceeded the 300 stems per ha target, and banksias are nearing the 250 stems per ha target for Carnaby's cockatoo food plants (Table 6). Overall, plant survival has been better in these areas which are lower in the landscape and closer to the water table (historically supporting transitional dampland vegetation). However, as they were restored only with planting and direct seeding, we do not expect to see comparable results with the topsoil areas in terms of understory diversity and density.

As shown in Figure 22 the structure of vegetation in restored areas is substantially different from reference sites and the Jandakot Airport topsoil source area and is likely to remain so for a long time. It is expected that these differences will decrease over time as native plants reproduce and their cover increases and supresses shade-intolerant annual weeds. Some indicators of ecosystem resilience have also been measured. For example, 140 native plant species had flowered, many of which were perennials, within 6 years (Fig. 23 and Appendix 2). Substantial pollinator activity and seed set were observed at both restoration sites (Fig. 24). However, long-term monitoring will be needed to determine time required for banksia woodland to recover and become resilient after restoration commences and how outcomes vary for different restoration methods.

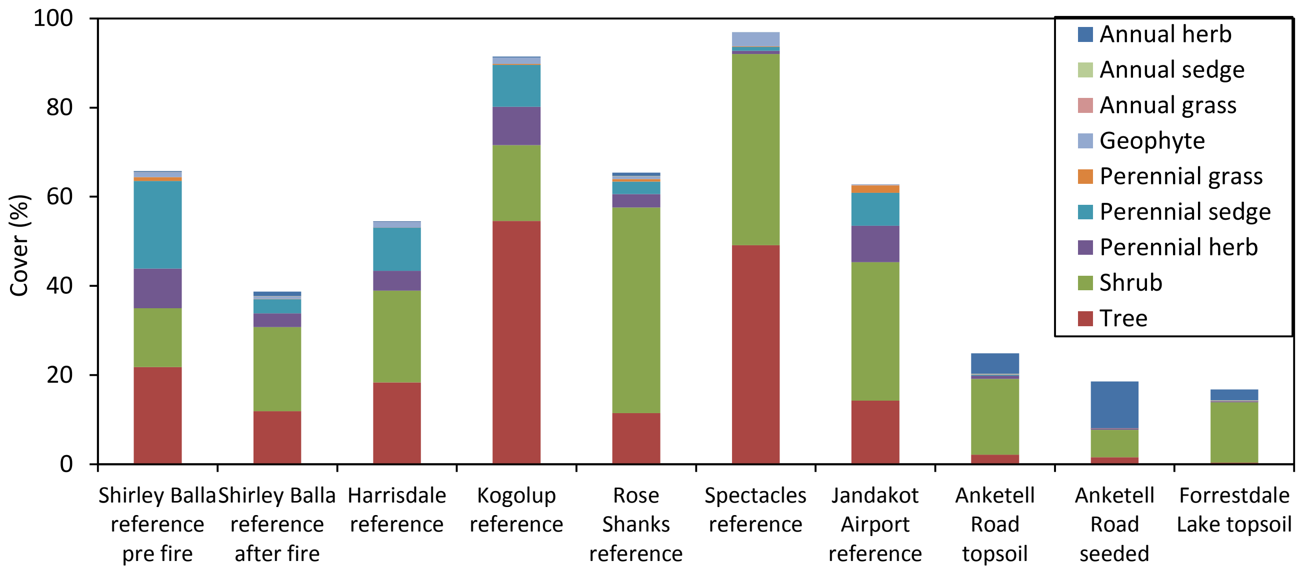


Figure 22. Comparison of the cover of native plants by growth form shows that vegetation structure varied considerably between reference and restored areas (last 3 columns), but there also were major differences between reference sites.

One of the key objectives of this project is to evaluate the relative cost-effectiveness of different methods for restoration of banksia woodland (preliminary costings are provided in the 2015 BWR annual report). As explained above, topsoil transfer was the most efficient method for restoring native plant diversity, but supplementary planting or seeding was also required to establish trees and shrubs that were absent from the topsoil seed-bank. It also needs to be noted that topsoil transfer has not always been successful in other restoration projects, since it requires topsoil source areas to be free from major weeds and diseases such as *Phytophthora* dieback and have sufficient amounts of seed in the topsoil, which is not always the case. The harvesting, transfer and respreading of the topsoil also needs to be carefully planned and executed for successful results. The topsoil must also be dry, only stored briefly, not be mixed with subsoil and should be transferred in autumn.

Table 6. The status of restoration outcomes in spring 2017 relative to targets set to assess vegetation in restoration sites (topsoil areas measured before the 2017/2018 summer). Only tree targets are used to assess areas at Anketell Road without topsoil, with other criteria statuses for non-topsoil areas shown for comparison.

Criteria	Target	Anketell Road topsoil	Forrestdale Lake topsoil	Anketell Road no topsoil
Total native species richness	Maximise native species richness. *There were **>80 spp.** present in in the topsoil source area at Jandakot Airport.*	Total of **160-162** native spp. (highly variable spatially)		71 native spp.
Average native perennial species richness per 10x10m quadrat	Return 60% of native species recorded in reference quadrats (**19 spp.**). *There were 27-39 native species per reference quadrat (average 31).*	Average **30** spp. per quadrat (range 20 – 44)	Average **20** spp. per quadrat (range 14 – 26)	Average 11 spp. per quadrat (range 1 – 20)
Tree diversity	Presence of all trees at reference plots (*Banksia attenuata, B. ilicifolia, B. menziesii, Eucalyptus marginata, E. todtiana* and *Nuytsia floribunda).*	**All present** - planted and seeded, but *Nuytsia floribunda* is uncommon and not present in survey quadrats. More than half of trees now measure over 1 m (tallest in a plot is 4 m).		
Tree density	Establish at least **300** stems per ha.	**243** stems per ha (25x25 m quadrats)	**183** stems per ha (5x5 m quadrats)	**362** stems per ha (25x25 m quadrats)
Carnaby's cockatoo food plants	This consists primarily of banksias - **250** stems per ha.	Banksias only: **152** per ha (25x25 m quadrats)	Banksias only: **167** per ha (5x5 m quadrats)	Banksias only: **222** per ha (25x25 m quadrats)
Average understory species richness per 10x10m quadrat	Return 60% of average number of native understory species in reference quadrats (**17 spp.**). *There were 25-36 native understory species per reference quadrat (average 29).*	Average **28** spp. per quadrat (range 17 – 42)	Average **18** spp. per quadrat (range 12 – 25)	Average **9** spp. per quadrat (range 1-18)
Total density of native perennial plants 10x10m quadrat	Establish **7,000** stems per ha.	Average **20,107** stems per ha (range 4,300 – 45,200) (42,986 stems per ha with seedlings)	Average **6,950** stems per ha (range 2,400 – 12,000) (7,750 stems per ha with seedlings)	Average **2,675** stems per ha (range 0 – 9,500) (5,931 stems per ha with seedlings)
Annual native plants	No target set (density is very much lower in reference sites).	17 species 4% foliage cover	15 species 2% foliage cover	10 species 6% foliage cover
Key understory species	Separate targets set for top 10 most important species from reference plots.	All are present, and most are common. An exception is *Hibbertia hypericoides* (ranked number 2 at Jandakot Airport), which is uncommon at the restoration sites.		Not relevant
Weed cover	Manage serious weeds, especially perennials, monitor annual weeds and manage if necessary.	Perennials: 1% (mainly couch & perennial veldt grass) Annuals: 4%	Perennials: 1% (mainly perennial veldt grass) Annuals: 8%	Perennials: 5% (mainly couch & perennial veldt grass) Annuals: 6%

4.9. Ecological Interactions

A. Flowering, Pollination, Seed Set and Succession

Over 86% of native species flowered within five years of the initiation of restoration activities (Fig. 23, Appendix 2). Long-lived perennial plants, especially trees, required several years longer to flower than most shrubs and herbs. Flowering of *Banksia menziesii* commenced in 2015 and flowering of *B. attenuata* and *Eucalyptus marginata* began in 2016. Flowering and seed set of *Melaleuca rhaphiophylla* and *M. preissiana* commenced in 2017. Only a few individuals of these trees have flowered so far. Plants that have flowered prolifically include species of *Jacksonia, Lechenaultia, Melaleuca and Kunzea*, as well as native orchids such as *Caladenia flava*. A wide range and abundance of generalist pollinators were observed at the restoration sites from year two onwards, especially in spring and summer, as shown in Figure 24CD.

There is evidence of plant succession in restored areas, due to reductions in numbers of some of the species which germinated abundantly from topsoil in years one and two. These species include *Hibbertia subvaginata, Jacksonia furcellata* and *Gompholobium tomentosum* which also tend to be most abundant after fire in banksia woodlands (see Section 8). Second generation seedlings of these species have recently been found in restoration areas, as well as the occasional banksia (Fig. 24AB). As these three species flowered prolifically they are likely to have already produced sufficient seed to replenish the topsoil seed bank. Declining cover by *Jacksonia furcellata,* which is a relatively short-lived disturbance opportunist, may be linked to increasing dominance by banksia trees in some areas (Fig. 24G).

B. Interactions Involving Animals and Fungi

Examples of harmful or beneficial ecological interactions observed at revegetation sites that provide evidence of ecosystem complexity and sustainability are briefly summarised here:

1. We observed frequent grazing of banksia seedlings by invertebrates.
2. Kangaroo grazing has increased inside fenced areas as they have begun to fund ways in.
3. Broomrape (*Orobanche minor*) was a common parasitic plant in restored areas but primarily attacks weed species. This resulted in reduced vigour of cape weed (*Arctotheca calendula*) in some areas.
4. Mycorrhizal and saprophytic fungi were observed to fruit in restored areas.
5. Parasitic galls are common on some plants, especially *Acacia* spp.
6. A smut fungus (*Tilletia ehrhartae*) that attacks perennial veldt grass (*Ehrharta calycina*) has been observed at several sites.
7. Mating of reptiles such as the western bearded dragon (*Pogona minor*) (Fig. 24E).
8. Nesting of native birds such as New Holland honeyeaters (*Phylidonyris novaehollandiae*) (Fig. 24F).
9. Increased grazing by kangaroos within fenced areas was observed in 2017 due to breaches in the fencing and as sight wires became less effective over time (Fig. 24H).

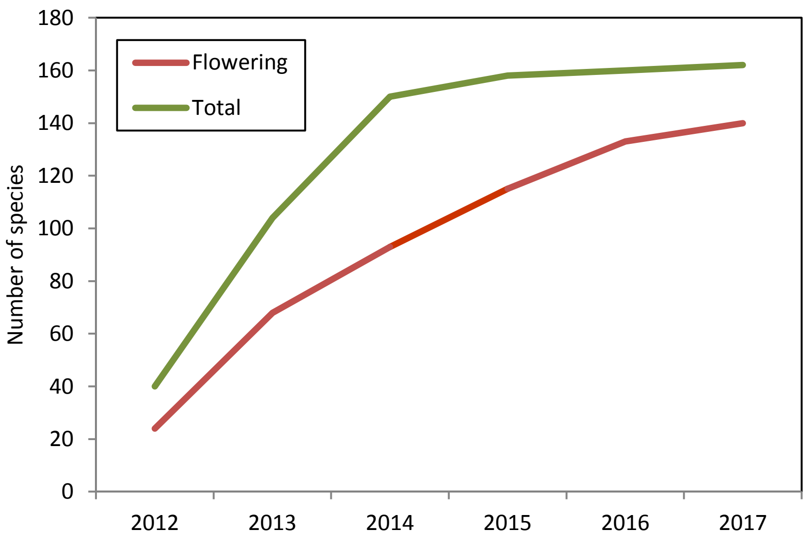


Figure 23. Increases in the number of plant species present and flowering (total for both restoration sites combined) over the first five years after topsoil transfer. The totals also include species that were planted or direct seeded. Over 86% of plants observed have flowered within five years of the initiation of restoration activities. All species are listed in Appendix 2.

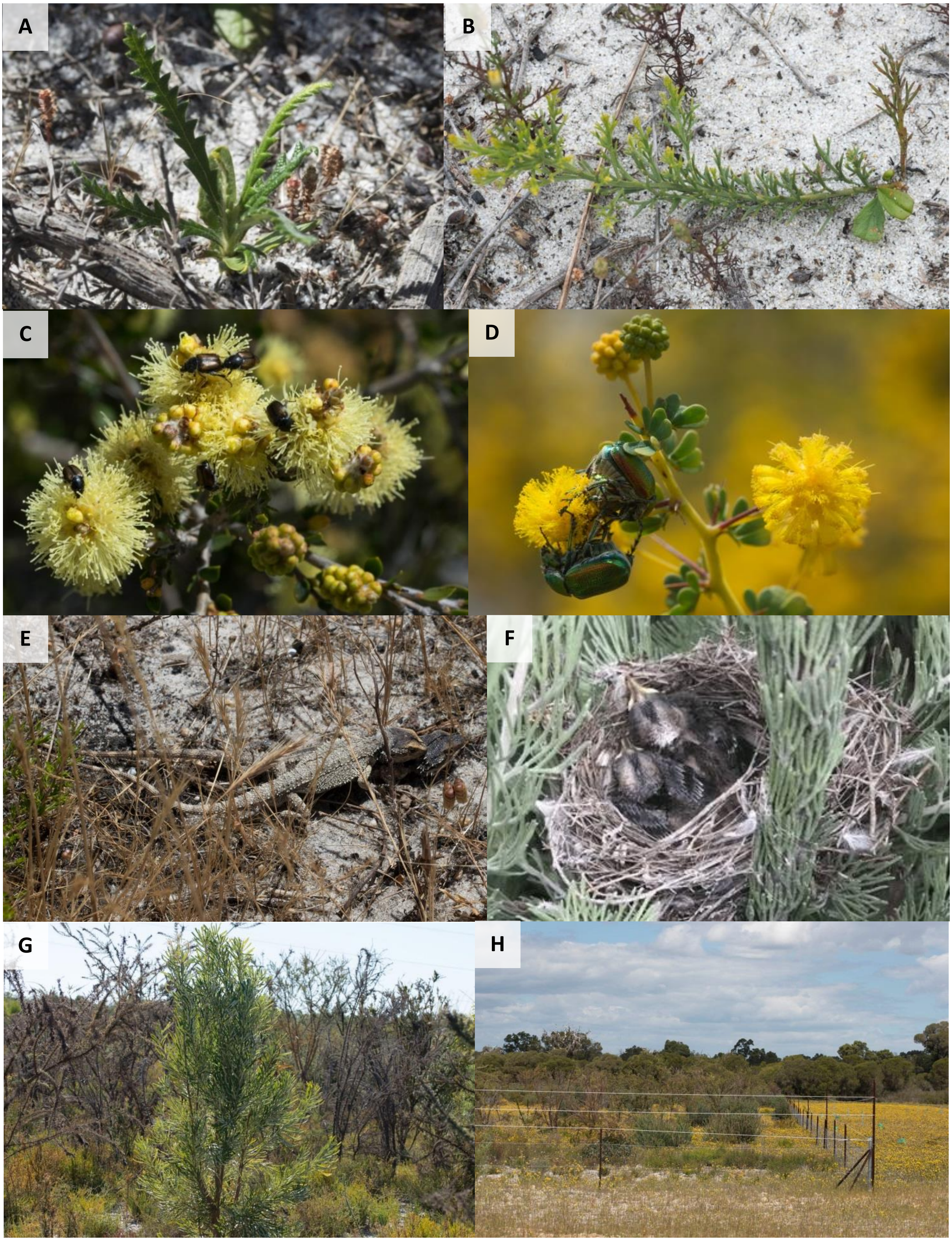


Figure 24. A. Self-sown banksia seedlings were first found in 2016 but were rare. **B.** Second generation seedlings of *Jacksonia furcellata* are becoming common as older individuals begin to senesce. **C.** Pollinators, such as nectar scarabs (*Neophyllotocu*s sp. on *Melaleuca thymoides*) are common in spring. **D.** Green spring beetles (*Diphucephala edwardsii* on *Acacia pulchella*) were abundant in winter. **E.** Mating pair of western bearded dragons (*Pogona minor*) in the restoration site. **F.** A pair of New Holland honeyeater (*Phylidonyris novaehollandiae*) nestlings in the Anketell Road restoration site in spring 2017. **G.** Declining *Jacksonia furcellata* next to a *Banksia attenuata* tree. **H**. Rabbit-proof fence with white sight wires to deter kangaroos.

5. Rehabilitation of Harrisdale Swamp

Harrisdale Swamp is located in Jandakot Regional Park in the suburb of Harrisdale. This Bush Forever site is approximately 110 ha in size, with 53 ha managed by DBCA's Regional Parks Unit, 48 ha managed by the Department of Planning, Lands and Heritage (DPLH) and the remainder privately owned. The majority of the site is in good condition but historical sand quarrying and dumping of garden waste has left some very weedy areas. The BWR project has been commissioned by the DPLH to help manage restoration of a highly degraded area of about 7 ha at the southwestern boundary of Harrisdale Swamp (Figs. 25, 26).

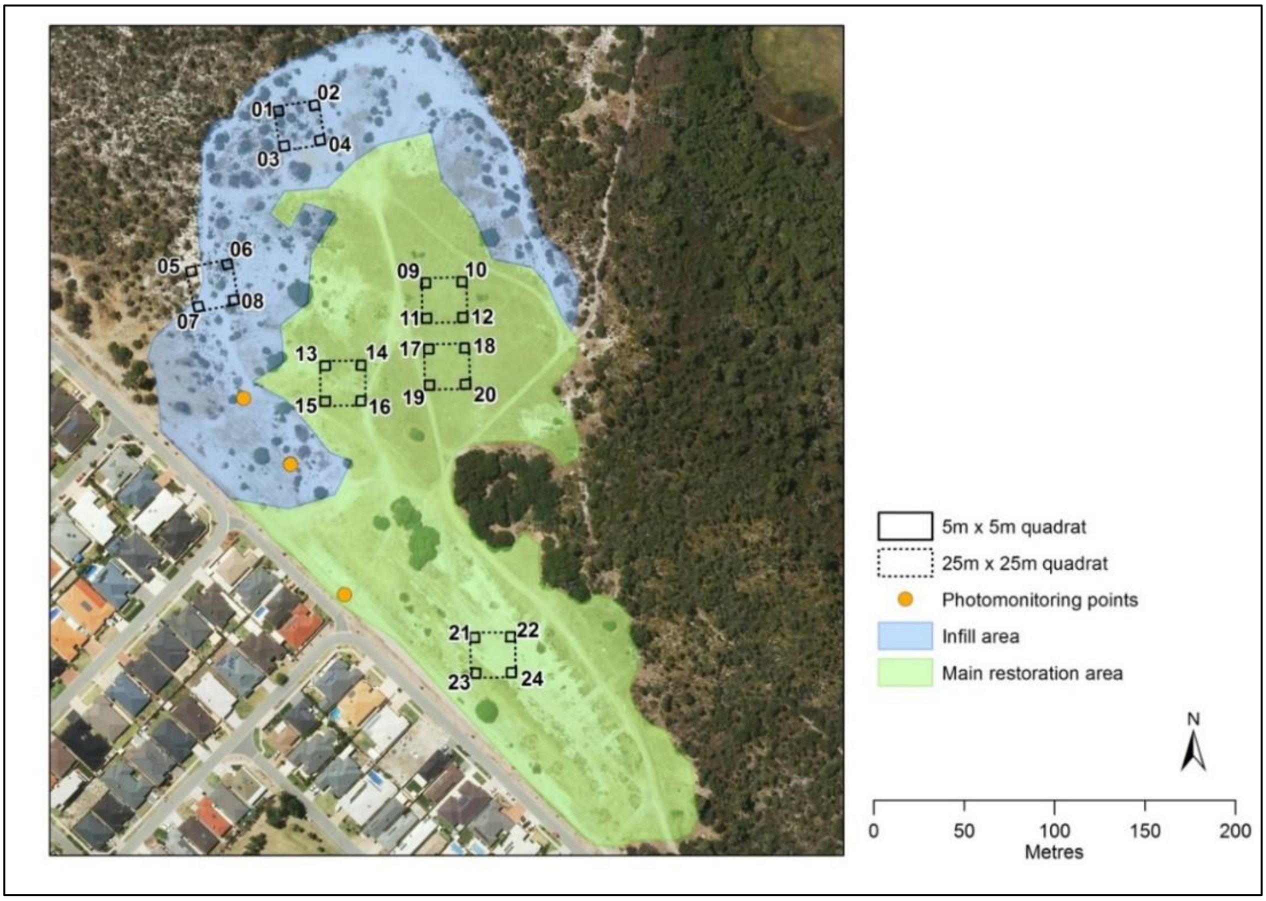


Figure 25. Aerial photograph of Harrisdale Swamp showing restoration areas and approximate locations of monitoring quadrats. Infill areas (highlighted in blue) contained some remnant indigenous vegetation while the main restoration area contained mostly weedy species (green). Both areas received respread topsoil from Banksia woodland clearing at Jandakot airport.

Figure 26. Main restoration area at Harrisdale Swamp prior to initiation of restoration showing severely degraded vegetation dominated by weed species.

Monitoring quadrats were established shortly after topsoil from clearing at Jandakot Airport was transferred and respread at Harrisdale in May 2017. DBCA staff and volunteers carried out the first vegetation surveys once the site was accessible (6th and 11th of July 2017) to provide baseline data for following vegetation recovery (Fig. 27). The monitoring methodology was adapted from procedures developed for BWR restoration activities at Anketell Road and Forrestdale Lake as part of the Jandakot Airport offset requirements. Monitoring of restoration outcomes occurred in a network of 5x5 m quadrats within 25x25 m quadrats, as shown in Figure 25.

Figure 27. A. Harrisdale Swamp restoration area immediately after site became accessible post top-soil spreading and road establishment. **B.** The establishment of monitoring quadrats by project staff and volunteers.

Data was collected on the number of individuals and foliage cover for all native perennial plant species, and foliage cover only for native annuals and weed species (both perennial and annual). Both dead and live cover were estimated to track changes due to weed control, as well as seedling germination and plant growth. The cover of litter and bare ground in each quadrat was also estimated. Herbivory can significantly impact vegetation recovery, therefore evidence of grazing inside each quadrat was also noted (presence of recent kangaroo and rabbit scats, and whether there was any obvious grazing damage to plants).

From the baseline survey in July 2017 (two months after topsoil respreading), to the follow-up survey in December, the frequency of native plants increased from 19% to 100% in the main (completely degraded) area, and from 75% to 100% in the infill area. Most of these new plants germinated from the topsoil seed bank (Fig. 28). Across the site, native plant species richness increased from 26 species (25 perennials and one annual) in winter, to 75 species (58 perennials and 17 annuals) in summer (Fig. 29). Even though most native plants were very small seedlings (Fig. 28), there was a noticeable increase in foliage cover for native species (Figs. 29, 30A), with an increase from almost nothing (<0.1%) to 2% in the main (completely degraded) area, and an increase of 16% to 21% in the infill area.

In the baseline survey in July all quadrats contained weed species, and the summer survey at the end of the growing season (December) found weed frequency remained at 100%. The number of weed species present increased, but more so for annuals (from 13 to 47 spp.) than for perennials (10 to 12 spp.) (Fig. 29). There were dramatic increases in weed cover, especially in the main (completely degraded) area, which increased from 2% to 14%, with an increase in the presence of both annuals (herbs and grasses) and perennial grasses such as *Cynodon dactylon* and *Ehrharta calycina* (Fig. 30B). The increase in weed cover in the infill area was much less, going from 2.5% in winter to 2.9% in summer (Fig. 30B). Many weed species occurred with high frequency across the site, and in summer the five most common weeds species were: perennial veldt grass (*Ehrharta calycina* - 100% of plots), *Briza maxima* (92%), smooth cats-ear (*Hypochaeris glabra* - 92%), *Ursinia anthemoides* (92%), and *Vulpia* sp. (88%). We expect that limited opportunities for weed control contributed to the increases in weed cover and frequency between the surveys. Last year control of *Arundo donax* was carried out, managed by DPLH. Additional weed management planned for this year includes control of couch grass (*Cynodon dactylon*), veldt (*Ehrharta calycina*), pigface (*Carpobrotus edulis*) and problematic annuals (e.g. narrowleaf lupin *Lupinus angustifolius*). In areas adjacent to the restoration site *Acacia longifolia* was effectively controlled last year by basal barking the trunks.

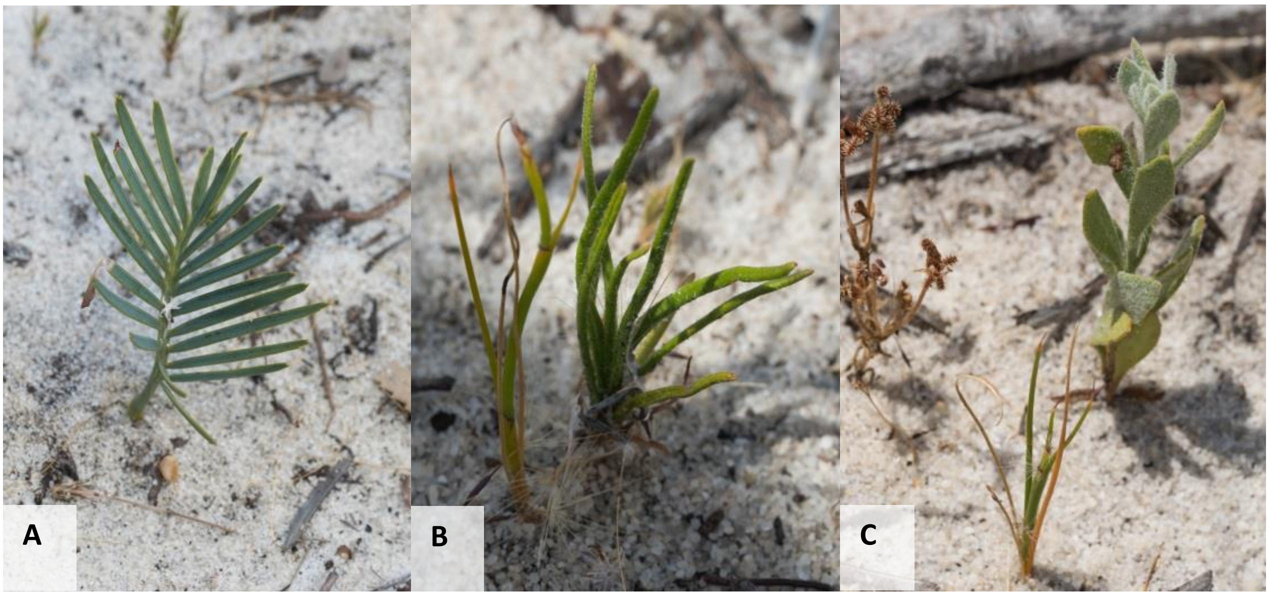


Figure 28. Examples of perennial native plant seedlings found in Harrisdale Swamp restoration areas (summer 2017). **A.** *Macrozamia fraseri* **B.** *Lyginia* sp. (left) and *Hibbertia huegelii* (right) **C:** *Dampiera linearis* (back right).

It should be noted that the data presented here represents very early stages of restoration. The winter survey was carried out shortly after respreading of the topsoil (July 2017) and the summer survey after only one growing season. It is evident that a wide diversity of native species has germinated from the topsoil seed bank since the first survey (Fig. 28). However, weed species richness and cover have also increased (Figs. 29, 30B), providing strong evidence for supporting ongoing weed management at the site.

Direct seeding by BWR Project staff with volunteer support is planned for May 2018, primarily to introduce species with canopy stored seed that are unlikely to recruit from topsoil, such as banksia species. Nearly 1 kg of seed from 22 different species and 33 accessions will be used. Ongoing vegetation surveys are required to track the success of the restoration and inform weed management, as well as guide any future seeding and planting. In our experience a single direct seeding operation is unlikely to result in sufficient cover of overstory plants, especially banksias. Consequently, several more years of seeding or infill planting, in conjunction with an ongoing weed management plan, will be required to establish sufficient density of overstory species.

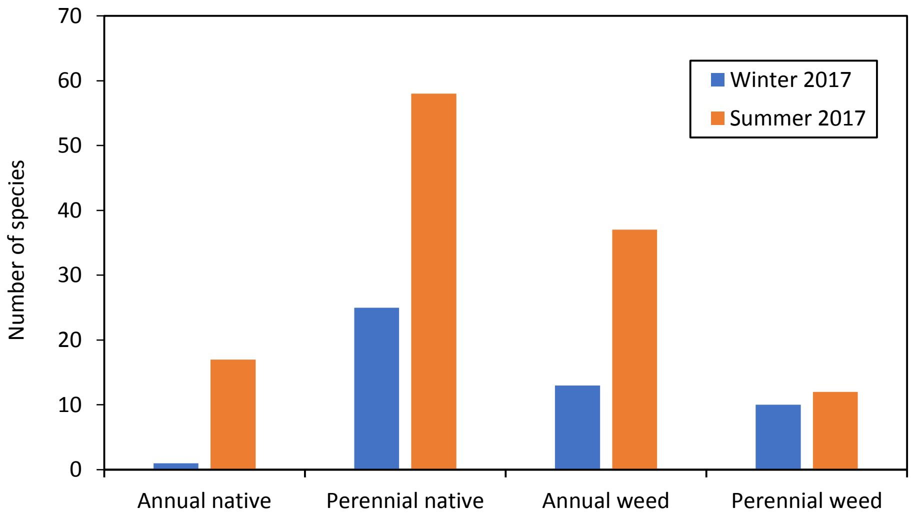


Figure 29. Change in species richness from winter to summer 2017 as the first generation of seedlings germinated from the transferred topsoil. There was an increase in the number of species in all categories (annual/perennial, native/weed), across the infill and main (completely degraded) areas of the site.

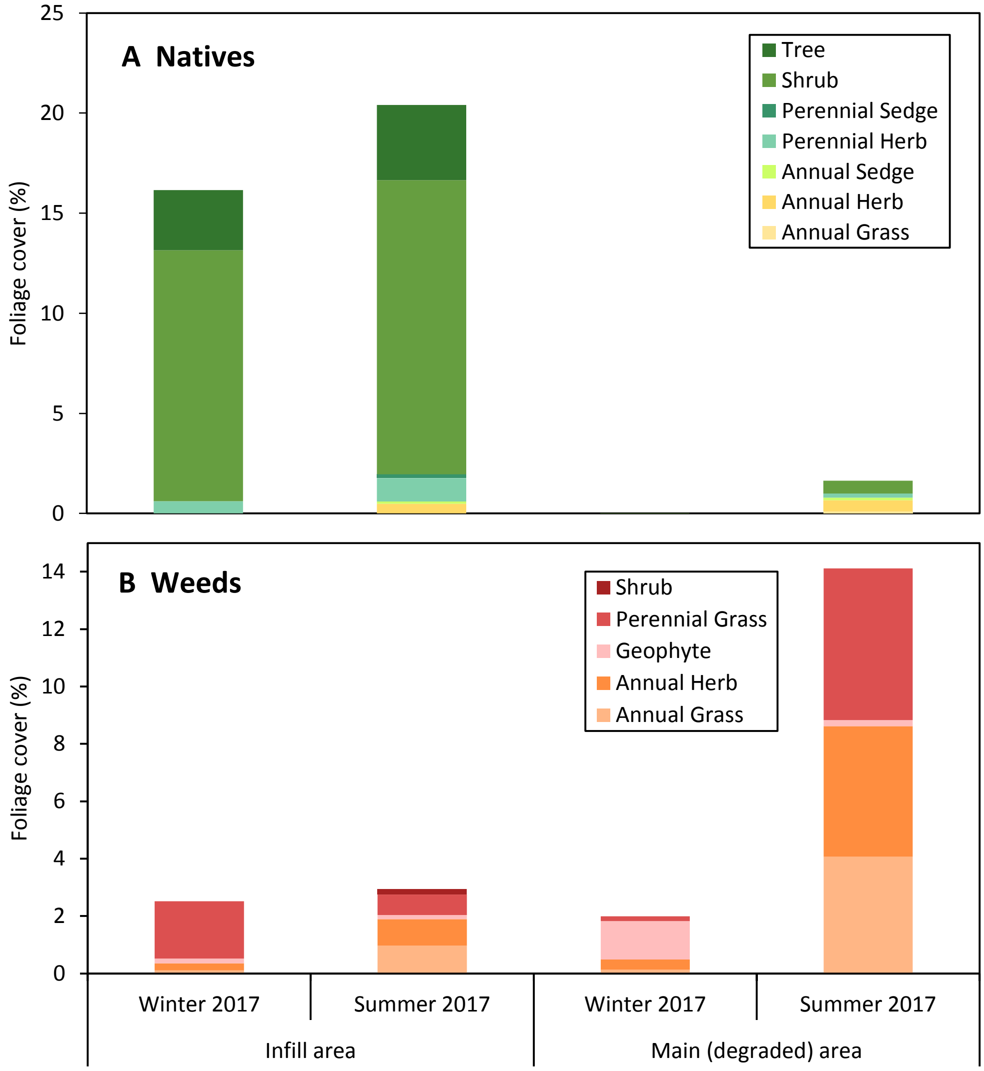


Figure 30. Changes in mean foliage cover of native (**A**) and weedy (**B**) species before and after germination from the transferred topsoil, in the infill area with some existing native plants (eight quadrats) and in the main completely degraded area (16 quadrats). Values less than 0.1% have been removed.

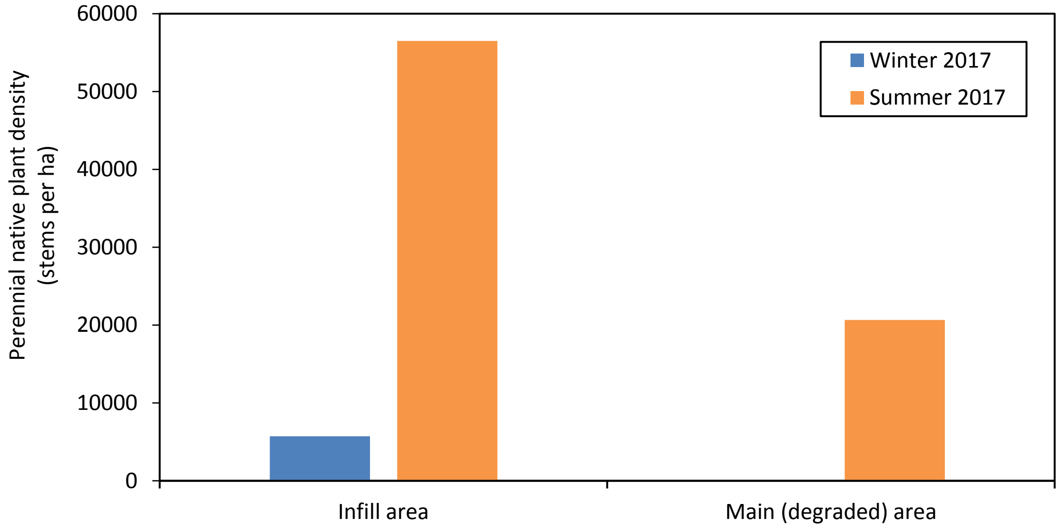


Figure 31. Comparison of perennial native plant density (stems per ha) over two surveys. The first survey in winter (July 2017) was prior to any germination from the topsoil transfer and the follow-up survey took place in summer (December 2017) after the first flush of germination from the topsoil. Infill areas with some pre-existing native vegetation are compared to the completely degraded main restoration area.

6. Rehabilitation of Habitats by Weed Management and Other Management Actions

Sites for weed control and other management actions funded by the BWR project are listed in Table 7. These areas were chosen after a strategic assessment of banksia woodland areas on the Swan Coastal Plain (Clarke et al. 2017), site visits and weed mapping in 23 reserves, of which 15 were newly mapped for this project. Large areas were identified where fencing and gates were required to control illegal access, rubbish dumping, and to reduce the spread of weeds and *Phytophthora* dieback by off-road vehicles. The BWR project contributed funding for major weed management, fencing and restoration works in seven of the most important natural areas on the Swan Coastal Plain to existing projects managed by DBCA's Swan Coastal District and the Urban Nature Program (Table 7).

The weed management objectives set by the BWR project are to:

1. Prioritise sites for management based on their environmental significance.
2. Restore ecological values of bushland and key biodiversity assets to a state requiring minimal ongoing maintenance.
3. Maximise ecological benefits through selective management of weed species.
4. Undertake management to maintain and/or improve bushland condition.
5. Ensure weed management fits within existing strategic management processes.

Weed management has focused on perennial weeds which are highly competitive with native plants. These include perennial veldt grass (*Ehrharta calycina*), Geraldton carnation weed (*Euphorbia terracina*), freesias (*Freesia alba* × *leichtlinii*), babiana (*Babiana angustifolia*), cape tulip (*Moraea flaccida*), yellow soldiers (*Lachenalia reflexa*), watsonia (*Watsonia meriana* var. *bulbillifera),* arum lily *(Zantedeschia aethiopica)*, tree tobacco (*Nicotiana glauca*) and woody weed species (see Table 7). The biology of each weed species dictates the timing and chemical applications required to achieve high mortality rates. This information was obtained from Florabase (florabase.dpaw.wa.gov.au) Management Notes by Kate Brown and Karen Bettink (Western Australian Herbarium 1998-). We also worked closely with contractors to ensure weed control was highly effective by careful specifications of the timing for spraying, areas to be sprayed and methodologies used. Spraying was carried out by five companies as specified in a panel tender. The standard set for the contractors was a minimum mortality rate of 80%.

A total of 27 sites (25 bushland and two restoration sites) had weed control works funded and managed by the BWR project (see Fig. 33 and Table 7). A summary of the 2017 works follows, with additional information in earlier BWR annual reports:

1. The Anketell Road restoration site was sprayed to manage perennial veldt grass in 2017 (22.6 ha), and 4 ha of the site sprayed to manage couch (*Cynodon dactylon*).
2. Fifty hectares of the Kogolup Lake site were sprayed for arum lily, watsonia and freesias.
3. Hand weeding by the Green Army and Work for the Dole teams have continued to control major woody weeds including Sydney golden wattle (*Acacia longifolia*) at Shirley Balla and Harrisdale Swamps (2-3 ha). Large plants have been cut down, and seedlings and saplings pulled out. Conservation Employees working for Regional Parks are continuing to control small outbreaks of Cape Arid Kennedia (*Kennedia beckxiana*) at Shirley Balla Swamp by spraying with herbicide. (Note: seed-free vegetative material was allowed to decompose on site.)
4. Control of a dolichos vine (*Dipogon lignosus*) outbreak at Harrisdale Swamp that was smothering trees was initiated in 2013 by cutting down vines and applying herbicide to the cut stems. DBCA employees and a Work for the Dole team have continued to apply control measures up to 2017 because new growth is recurring regularly.
5. The control of weedy eucalypts has continued in Jandakot Regional Park at Shirley Balla Swamp and at Taylor Gibbs Reserve. Prolific germination of seed and rapid growth of *Eucalyptus grandis* and hybrid eucalypts followed a fire that went through Banjup in February 2014 (Fig. 32A). These species that pose a new threat are largely progeny of fast-growing eastern Australian species (some of which can attain heights of up to 50 m) planted on surrounding private properties. Control of these weedy eucalypts is being undertaken by Conservation Employees employing two methods, dependent on the size tree: thinner saplings are 'cut and painted' (stems are cut and then painted with glyphosate herbicide, Fig. 32B) and larger saplings and mature trees are 'basal barked'

(oil-soluble herbicide, Access™, is mixed with diesel and the full circumference of the trunk or stem of the plant is sprayed with this mixture). These works will continue into the future.

6. Over 108 ha of *Carpobrotus edulis* (pigface) was sprayed in Shirley Balla Swamp and The Spectacles. This species has become a very significant problem after fires went through the two sites opening the canopy and allowing germination and vigorous growth.
7. Weed management for perennial veldt grass commenced in 2013 but has been interrupted twice. The first was in 2015 due to funding issues (see Section 1.1) which meant only veldt grass monitoring quadrats (<1 ha) were sprayed that year. This lead to an increase in veldt grass cover and flowering and seed set overall. In 2016, spraying recommenced but was limited to restoration sites and veldt grass monitoring areas (total 120 ha). In 2017, delays due to retendering for weed control and inclement weather contributed to a reduction in the number of sites receiving treatment, with a total of only 40 ha being sprayed at The Spectacles (Beeliar Regional Park). It will be necessary to respray some areas in 2018 to ensure perennial veldt grass does not regain its previous dominance.
8. The BWR Project undertook a second round of weed mapping at the weed management sites in 2017 (the first round was in 2013). This showed that the area highly infested with veldt grass had substantially decreased but not the total area (Fig. 35). Veldt grass cover increased by about 3 ha at Shirley Balla Swamp due to the combined effects of fire and delays in the second round of spraying. In total there was a slight increase in the total areas with low level veldt grass infestation, but many areas had less than 5% cover so were below targets for weed management. In contrast, areas that were highly infested deceased by over 80%. As explained in the next section veldt grass cover also declined on some years in the absence of spraying, probably due to low winter rainfall.

Overall conclusions on the effectiveness of weed management and its impact on native plants are described in the next section.

Figure 32. Outbreaks of weedy eastern Australian eucalypt species occurred in Jandakot Regional Park after the 2014 fire. **A.** Thicket of two-and-a-half-year-old *Eucalyptus grandis* saplings with a DBCA staff member cutting through a sapling in 2016. Control involves cutting and painting or basal barking with herbicides. **B.** The same site in 2017 (white arrows indicate the same individual plant). Saplings that were cut and painted, or basal barked, have all died. Work is continuing to control the remaining saplings.

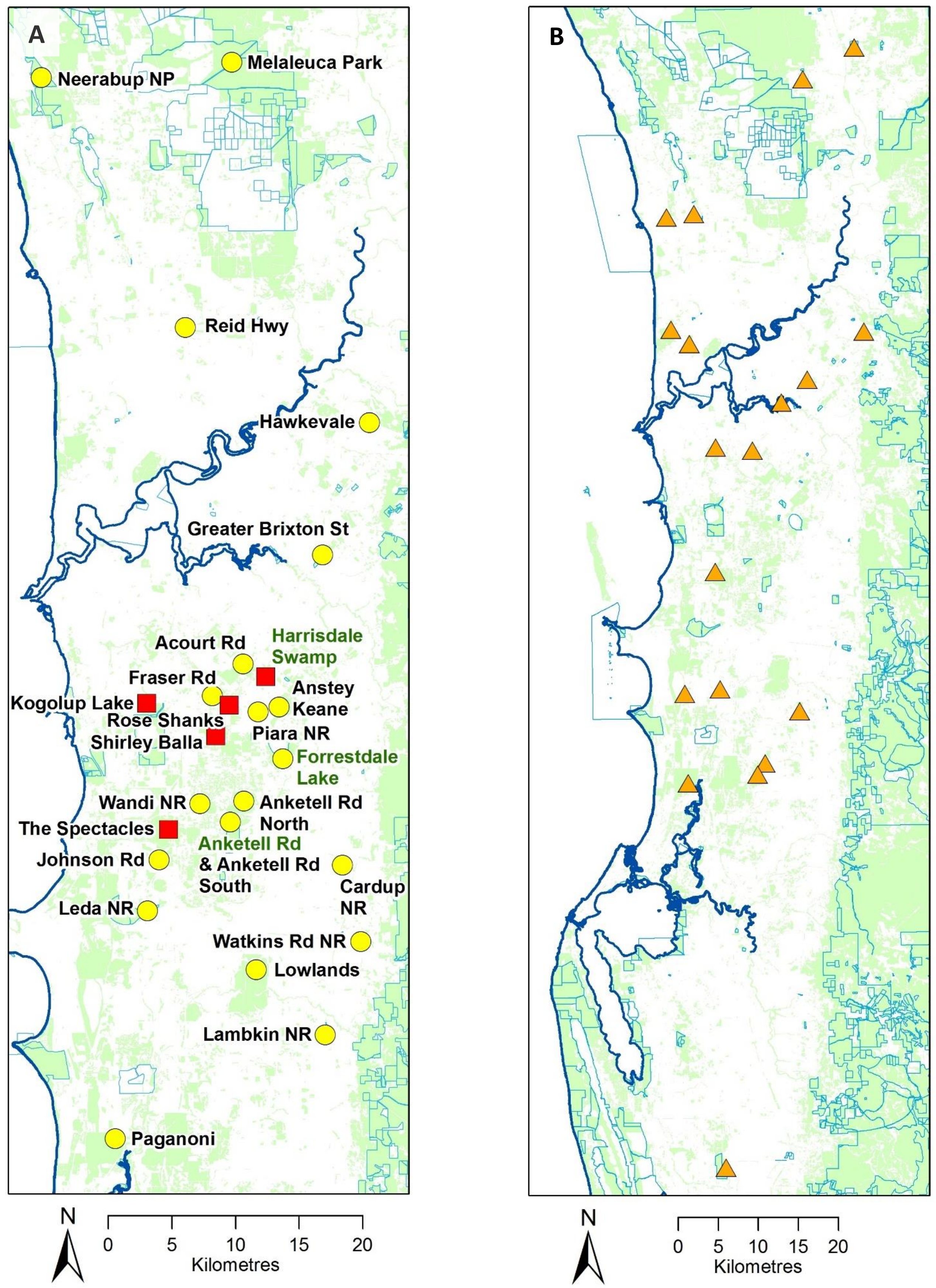


Figure 33. A. Areas where weed and other management funded by the BWR project occurred between 2012 and 2017 (yellow circles). Perennial veldt grass control sites with monitoring quadrats are shown as red squares. Green labels indicate location of restoration sites. **B.** Locations of projects by community groups funded by Perth Banksia Woodland Community Restoration Grants (see the 2016 BWR annual report).

Table 7. List of 27 sites where weed control and fencing was funded by this project. Twenty-five sites with relatively intact vegetation were chosen in addition to the two main restoration sites (shaded pink). They are listed in order of importance following a selection process (Clarke et al. 2017).

Site Name (Project Management for weeds and fencing*)	Rank	Bush Forever Site No.	Weed mapped area (ha)	Weed management area (ha)	Fencing (km)	Management details (weed and fencing)
Anketell Rd North Bushland, Jandakot Regional Park (BWR)	1	347	204	50		Veldt grass, arum lily, freesia, woody weeds
Anketell Rd Restoration Site, Jandakot Regional Park (BWR)	1	Adj. 347 & 348	18	20	2.5	Veldt grass, couch, pigface etc. Hand weeding - bulbs, Geraldton carnation weed, pigface etc.
Wandi Nature Reserve, Jandakot Regional Park (UN, BWR)	1	347	UN	20		Veldt grass, freesia, pigface to protect DRF
Melaleuca Park (SCD)	3	399	53	10	1	Geraldton carnation weed, woody weeds, fencing along Neaves Rd
Forrestdale Lake Nature Reserve (Friends of Forrestdale, BWR, SCD)	4	345		10	repairs	Arum lily, bridal creeper, pampas grass, etc.
Forrestdale Lake Restoration Site (BWRP)	4	345	6	4	2	See Anketell Rd Restoration Site above
Lowlands Bushland (UN, SCD)	5	368	UN	50		Arum lily, castor oil, cotton bush
Greater Brixton St Wetlands (UN, SCD)	7	387	UN	10	0.15	Ongoing eradication of bamboo, bulbs, couch in TEC, fences and gates
Anketell Rd South Bushland, Jandakot Regional Park (BWR)	12	348	51	12		Veldt grass. Hand weeding - Geraldton carnation weed, gladiolus, pigface
Anstey Keane, Jandakot Regional Park (UN, BWRP)	15	342	UN	50		Veldt grass, black flag, cape tulip, Geraldton carnation weed, Victorian tea-tree
Acourt Rd Bushland, Jandakot Regional Park (BWR)	19	389	67	20		Veldt grass, freesia
Kogolup Lake, Beeliar Regional Park (BWRP)	21	391	60	56		Veldt grass, arum lily, pigface, Geraldton carnation weed, freesia, watsonia
Shirley Balla Swamp Reserve, Jandakot Regional Park (RP, BWR)	22	263	131	60		Veldt grass, arum lily, bulbs, Cape Arid Kennedia, Geraldton carnation weed, pigface, Sydney golden wattle, tree tobacco, weedy eucalypts
Cardup Nature Reserve (SCD, BWRP)	23	352	75	10	0.5	Veldt grass, African lovegrass, woody weeds in TEC, fencing
Watkins Rd Nature Reserve (SCD)	25	360	SCD	50		Various weeds followed by revegetation
Paganoni Swamp, Rockingham Lakes Regional Park (UN)	33	395	UN	20		Various weeds (follow-up spraying)
Neerabup National Park (SCD)	36	383			1.8	Fencing and gates
Fraser Rd Bushland (SCD, BWRP)	37	390	20		2	Veldt grass in DRF habitat
Rose Shanks Reserve (in Fraser Rd Bushland) (City of Cockburn)	37	390	CoC	30		Veldt grass, Geraldton carnation weed
Leda Nature Reserve (SCD, BWRP)	42	349	80	28	1	Veldt grass in prescribed burn area, fencing
Harrisdale Swamp, Jandakot Regional Park (BWR, RP, Friends of Forrestdale)	43	253	53	40		Veldt grass, dolichos vine, Geraldton carnation weed, pampas grass, Sydney golden wattle
Hawkevale Bushland (SCD, BWRP)	47	122	10	10	0.97	Veldt grass, woody weeds, fencing, rubbish removal
Reid Highway Bushland, Mirrabooka/Malaga (UN)	51	385	85	33		Veldt grass
Piara Nature Reserve, Jandakot Regional Park (BWR)	63	262	36	15		Veldt grass, arum lily, Geraldton carnation weed, pampas grass, woody weeds
Johnson Rd Bushland, Kwinana (SCD)	69	272	10	2		Cape tulip, etc. to protect DRF and other assets
The Spectacles, Beeliar Regional Park (BWR)	79	269	50	50		Veldt grass, arum lily, Geraldton carnation weed, pigface, bulbs, woody weeds
Lambkin Nature Reserve (SCD)	95	375	SCD	2		African lovegrass, watsonia, etc.
TOTAL			**1009**	**662**	**12**	

*BWR = Banksia Woodland Restoration Project, RP = Regional Parks, UN = Urban Nature Program, SCD = Swan Coastal District, CoC = City of Cockburn, DRF = Declared Rare Flora, TEC = Threatened Ecological Community.

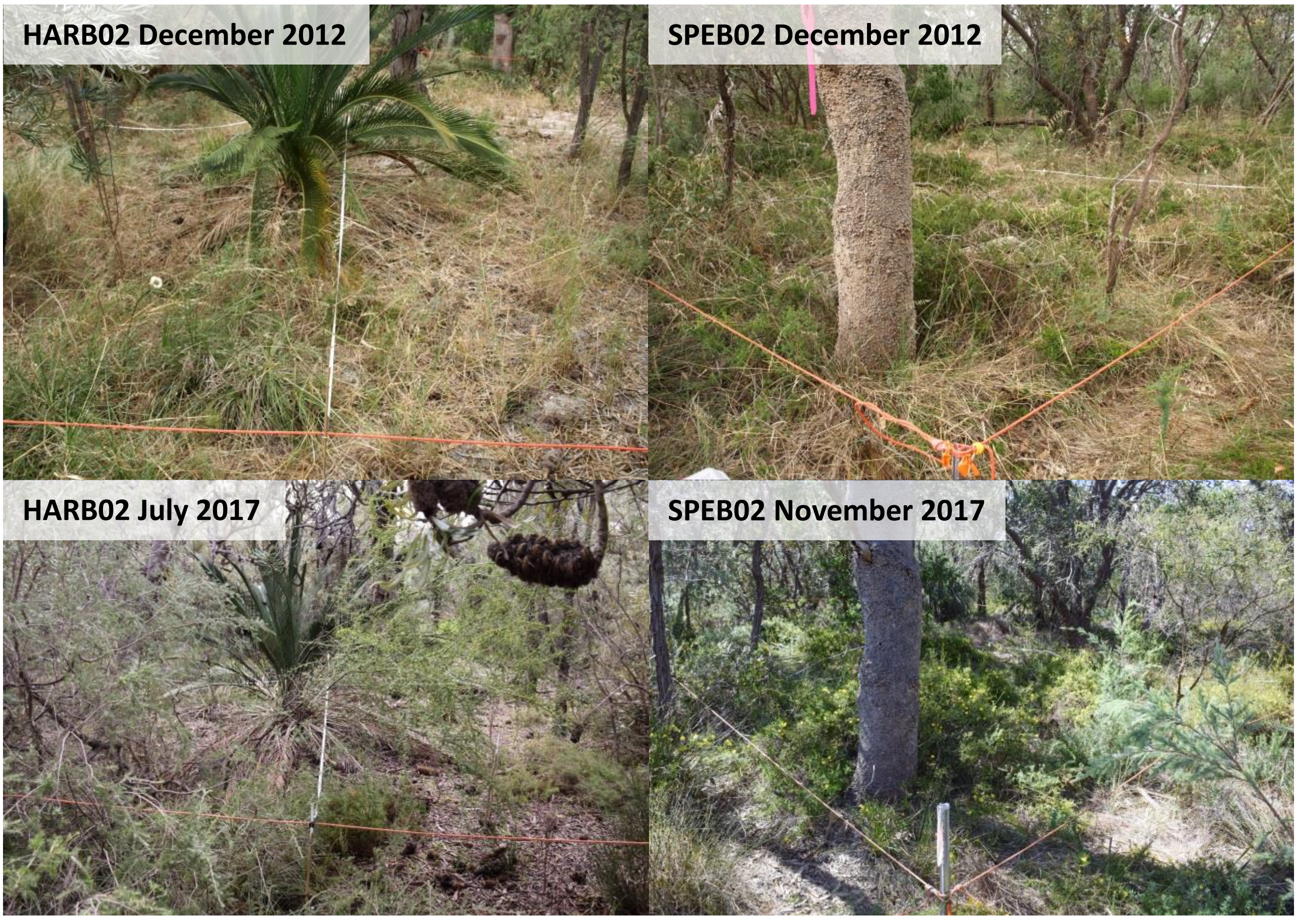


Figure 34. Photographs of one quadrat at Harrisdale (HARB02) and one at The Spectacles (SPEB02) before and after five years of annual spraying for perennial grasses. The grassy component of the understory is visibly reduced in the 2017 photographs.

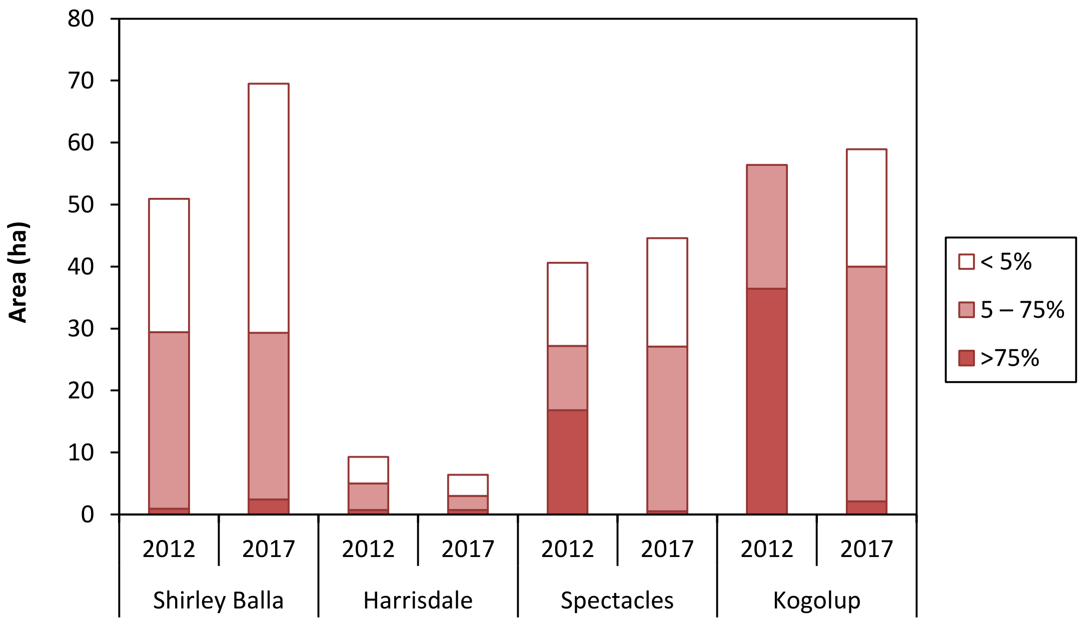


Figure 35. Weed cover mapping of four of the largest weed management sites. Areas mapped as severely infested (>75% cover) have reduced considerably overall, but the total area containing veldt grass has not decreased. Note that areas with less than 5% veldt grass cover have reached targets for weed sparaying.

7. Monitoring the Outcomes of Weed Management

A banksia woodland monitoring program was established in 2013. The program has 31 permanent 10x10 m quadrats in five reserves where weed management is underway (Fig. 33A). This monitoring framework was initially established to monitor the response of native plants to the control of perennial veldt grass (*Ehrharta calycina*), the most significant environmental weed at these sites. Sprayed quadrats were treated with Fusilade™ every year from 2013 to 2017 and these sprayed quadrats were compared with unsprayed and reference quadrats. To investigate the impacts of veldt grass control on the diversity, density and cover of native plants and weeds, three major flora surveys were conducted in 2013, 2015 and 2017. Data from these surveys show:

1. Increased visibility of native plants after veldt grass is eliminated as shown in photographs of two of the monitoring quadrats before and after weed spraying (Fig. 34). The cover of understory native perennials has generally increased (Fig. 36A).
2. The overall dominance of perennial weeds substantially decreased after spraying removed most perennial veldt grass and further weed management activities removed many of the other perennial weeds, such as freesia and Sydney golden wattle (Fig. 36B).
3. Spraying with grass-selective herbicide for veldt grass control was very effective in all quadrats that were sprayed in two or more consecutive years (Fig. 34B) but it is considered that at least three consecutive years of selective herbicide spraying are required to effectively manage perennial veldt grass because some tillers survive spraying and new germinants appear each year.
4. The cover of understory native annuals has increased in some quadrats but the cover of annuals varies substantially from year to year because of seasonal differences in rainfall (Fig. 36A). Annual rainfall for 2017 at 862 mm was slightly above average, but the rainfall pattern was unusual with abnormally high rainfall in late summer (February) and a drier than normal autumn (Fig. 7). It is likely that this had a major impact on germination and survival of annual species. The significant increase in native annuals at Rose Shanks is attributable to the increased prevalence here of the native everlasting *Podotheca*, which can behave like a weed.
5. Small weedy annuals also appeared to respond to veldt grass management by increasing in cover at most sites (Fig. 36B) but, as with native annuals, their cover varies substantially from year to year due to differences in rainfall. Annual weeds do not seem to displace native species and are of lesser concern than perennials.
6. As shown in Figure 36A, cover has generally increased for native perennials including shrubs and herbs after control of veldt grass. There are no strong overall trends evident for other categories of native species due to very substantial differences in vegetaiobn composition between sites. Weeds show decrease in cover, except at Rose Shanks where the bulbous weed freesia recovered after control efforts in 2015 (Fig. 36B). Veldt cover is now slowly increasing in Harrisdale, Kogolup and The Spectacles since there was no veldt control in 2017.
7. Tree seed germination has substantially increased in sprayed plots relative to unsprayed plots (Fig. 37).

It has been decided to continue spraying and monitoring a subset of the banksia woodland monitoring quadrats into the future to follow the response of native plants to perennial veldt grass control particularly since differences due to weed control develop slowly and tend to be masked by high natural variability in vegetation between sites.

Data on floristic diversity, density and cover from these 31 banksia woodland monitoring quadrats, in addition to the data from another 20 quadrats surveyed by the Project in primarily upland banksia woodland in Jandakot Regional Park, Forrestdale Lake and Jandakot Airport, have been published and are available for use by the public. The data are available at the department's NatureMap website (naturemap.dpaw.wa.gov.au) and will be updated with the latest survey results and with monitoring data from the BWR Project's restoration sites at Anketell Road and Forrestdale Lake during 2018.

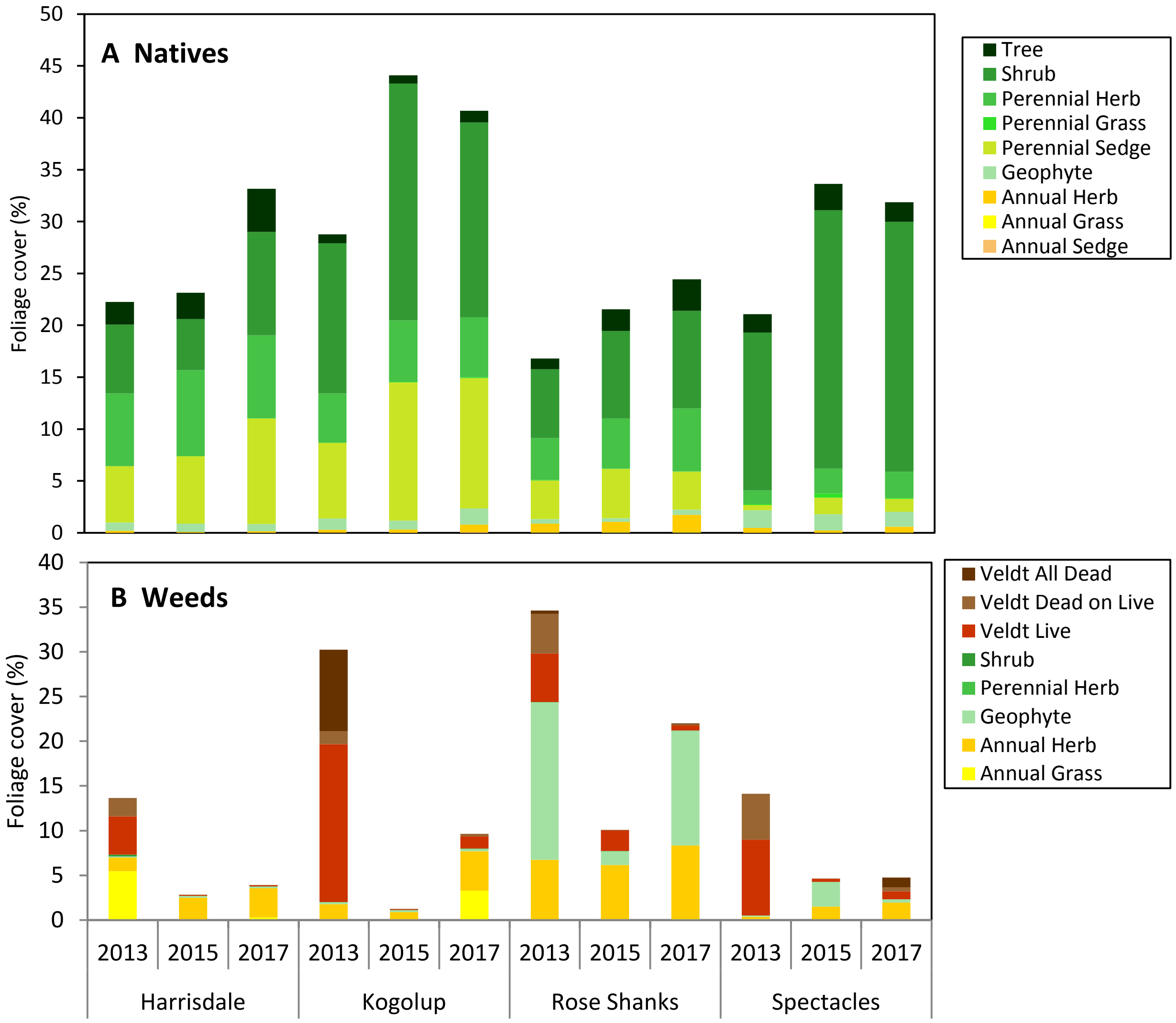


Figure 36. Changes in understory foliage cover of native (**A**) and weedy (**B**) species following herbicide spraying for perennial grasses over 2013-2017. Data are averages from two or three sprayed quadrats at four different study sites.

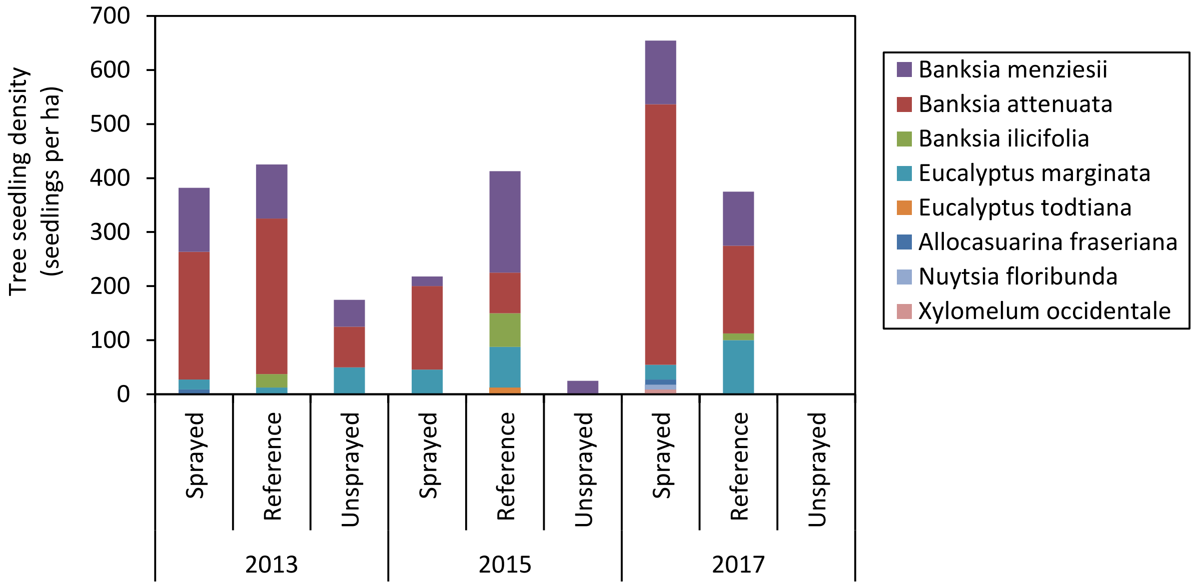


Fig 37. Tree seed germination rates in 11 sprayed, eight reference and four unsprayed quadrats for the years 2013, 2015 and 2017.

8. Monitoring the Recovery of Banksia Woodland after Fire

A severe bushfire in Banjup in February 2014 burnt all seven BWR monitoring quadrats in Shirley Balla Swamp Reserve within Jandakot Regional Park (Fig. 33), but the remaining weed management monitoring quadrats in other reserves were unaffected. The burnt quadrats were located in areas with high or low veldt grass cover and included quadrats that were sprayed or remained unsprayed to assess weed management outcomes. These plots can no longer be compared to unburnt plots to monitor weed management, but have since been used to monitor changes in plant density, cover and diversity after fire. Various methods of estimating vegetation cover at the Shirley Balla site before and after the 2014 fire have been compared by the BWR team and the results compiled in a paper that has recently been accepted for publication (Brundrett et al. 2018). Monitoring occurred monthly for the first six months – quarterly until November 2015, then biannually until the end of 2017, almost four years after the fire. The results that are currently available are described briefly here (further details will be published elsewhere):

1. Plant cover was measured by visual estimation and photographic methodologies and is steadily increasing, reaching 25% by 19 months post fire for understory (Fig. 38A). The overstory is also increasing but at a much lower rate (i.e. 5% by 19 months post fire, Fig 38B). The rapid recovery of the understory and the more gradual recovery of the canopy in plots are illustrated by monitoring photographs in Figures 39 and 40.
2. Many trees gradually recovered by resprouting from the canopy or base, as shown for a Christmas tree (*Nuytsia floribunda*) in Figure 41.
3. The average mortality of trees resulting from the Shirley Balla fire was much higher for small trees with stem diameter less than 20 cm (Fig. 42). There was a 39% total mortality of banksia trees, with many surviving trees resprouting from the trunk or base only, as shown in Figure 42. Some resprouting trees later died. Large trees were more likely to resprout in the canopy and thus recover more rapidly than smaller trees.
4. Resprouting plants dominated initially, but those that recruited from seed became almost as diverse during the first winter after the fire (months four to eight in Fig. 43). Species that recover by resprouting from the base, stem, rhizome, tuber and roots are all represented after the fire (Fig. 43).
5. Native plant cover was much greater than weed cover for the first 19 months after the fire (Fig. 44). Cover of *Austrostipa compressa*, a native fire-opportunist annual grass, was only high during the first year post fire (Fig. 44) but seeds will remain in the soil seed bank until the next disturbance event.
6. There were major initial impacts on perennial veldt grass after the fire due to weed control in 2013, resulting in less than 1% cover in sprayed quadrats in 2014 (Fig. 45). However, veldt grass cover rapidly increased again due to lack of spraying in 2014 and 2015, before it was sprayed successfully again in 2016.
7. Cover of other weeds, predominantly annuals, peaked over winter in the first 19 months post fire (Fig. 45).
8. Floristic changes summarised in Table 9 show that after the fire there was a loss of four native and one weed species from the plots. There also was a gain of 13 native species (mostly short-lived fire-responsive species) and a gain of 30 weed species.
9. There was spectacular banksia seed germination in the first winter after the fire (2014), with an average of about 6,000 banksia seedlings per ha, compared to about 250 per hectare before the fire (Fig. 46). Banksia germination, which occurred from seed shed from cones in the canopy, was rare in 2015 and absent in 2016, but was again occurring in 2017, probably as a result of seed from trees that have recovered, and flowered, after the fire. About 70% of banksia seedlings that germinated in 2014 survived the summer of 2014/15 (these are called saplings in Fig. 46). In 2017 the first banksia (*Banksia menziesii*) that germinated after the fire flowered, three years after germinating. There also were many *Nuytsia floribunda* seedlings in one area in 2015 (data not shown), after a massive post-fire flowering display (Fig. 41). The low pre-fire germination rate of banksias in 2013 of 100-500 per ha is typical of germination in other banksia woodland sites (Fig. 37). It seems likely that banksia seedling survival was promoted by weed control in all sites with or without fire.

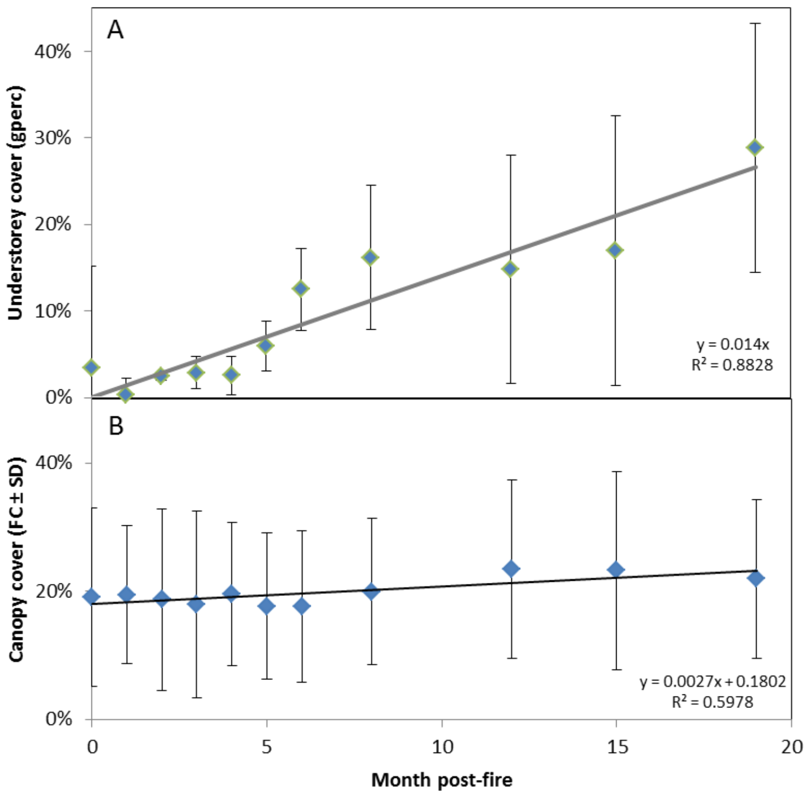


Figure 38. A. Changes in total understory cover calculated from downward photos of 1x1 m subplots over 19 months following the fire

B. Changes in canopy cover over the 19 months following the fire calculated from upward photos.

In both cases, cover is averaged across 63 sub-quadrats in seven quadrats with the standard deviation (SD) shown. Cover was measured from photos using computer algorithms as explained elsewhere (Brundrett et al. 2018).

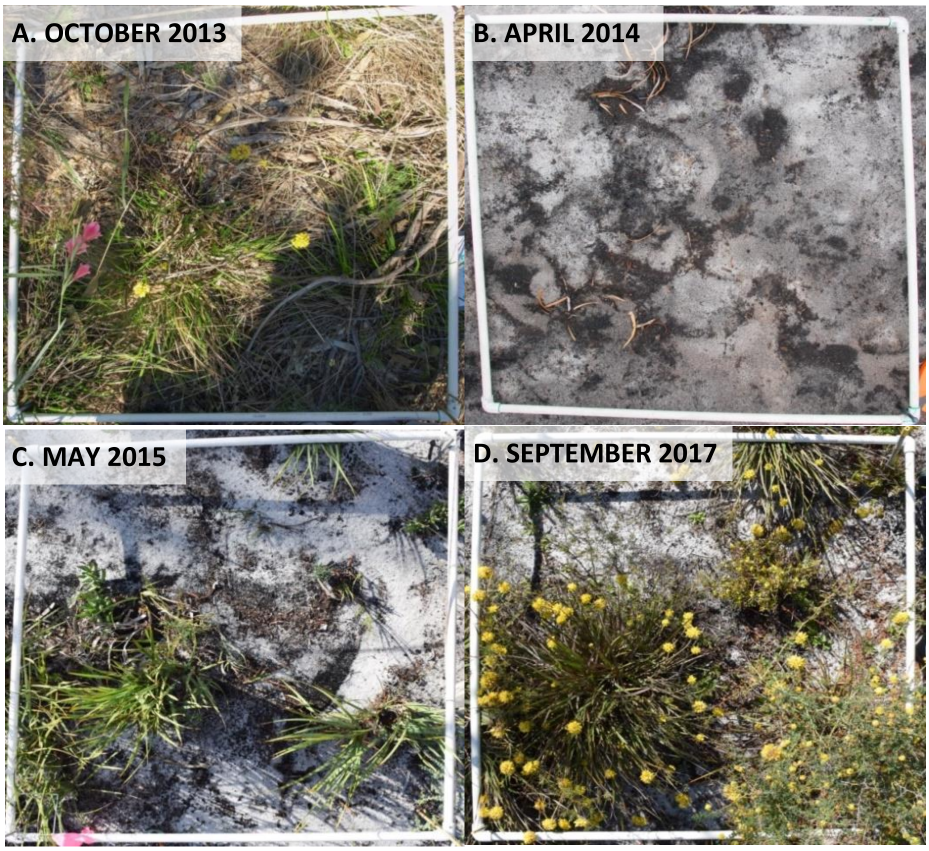


Figure 39. Photographic time series of the same 1x1 m subplots at Shirley Balla over five years, both before (A) and after (B-D) the fire of February 2014.

Vigorous growth of resprouter species was evident after one year (C). Two years later the resprouter species *Conostylis* and the seeder species *Acacia pulchella* (D) are both flowering.

These photographs were used to calculate understory cover with a computer algorithm (Fig 38A).

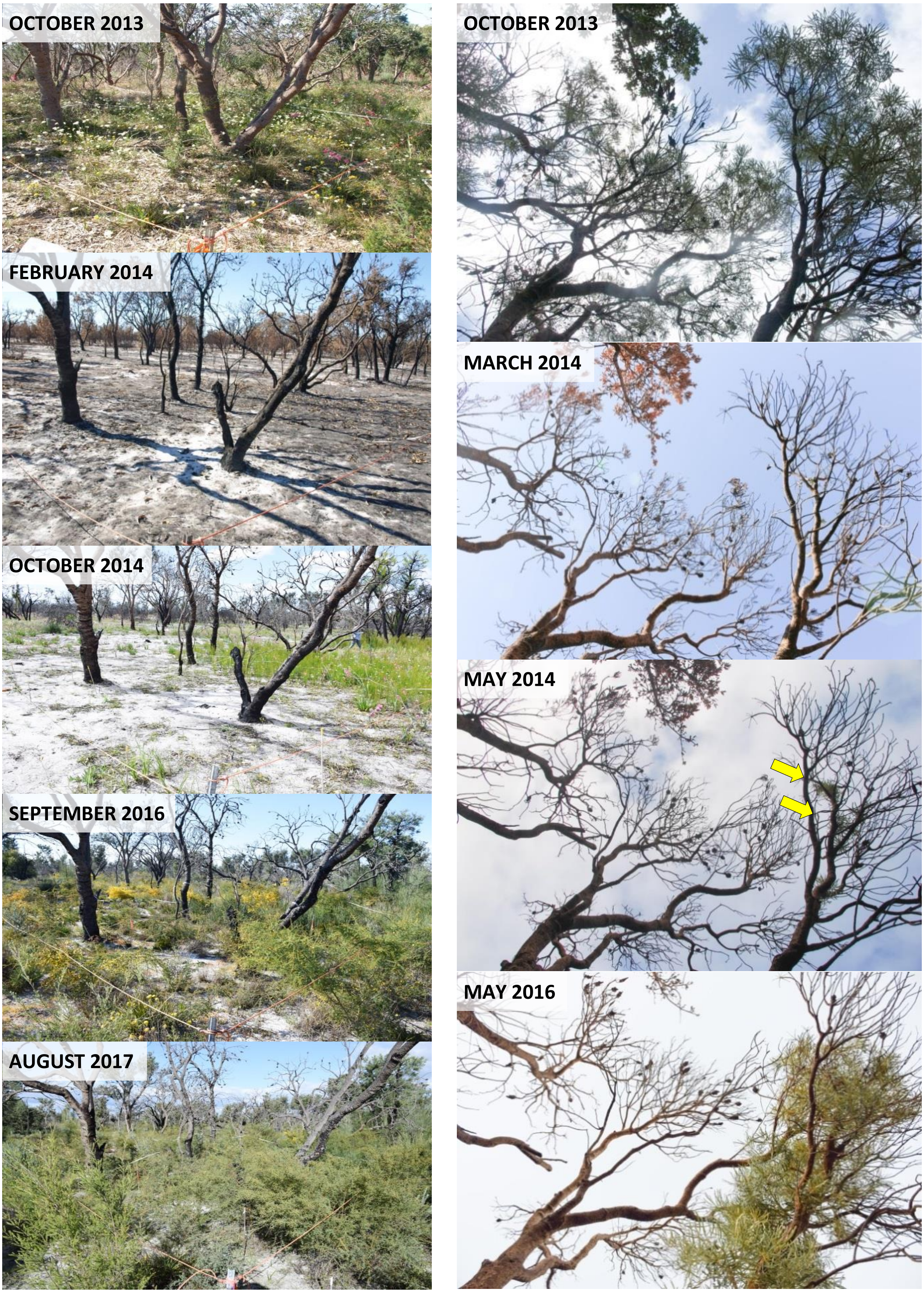


Figure 40. Time series photography of the recovery of banksia woodland in two quadrats at Shirley Balla Nature Reserve. **Left:** Vegetation before (2013) and after fire (2014-17). **Right:** The fire caused the death of large branches and entire trees but surviving trees are slowly producing a canopy of new branches arising from epicormic buds (yellow arrows).

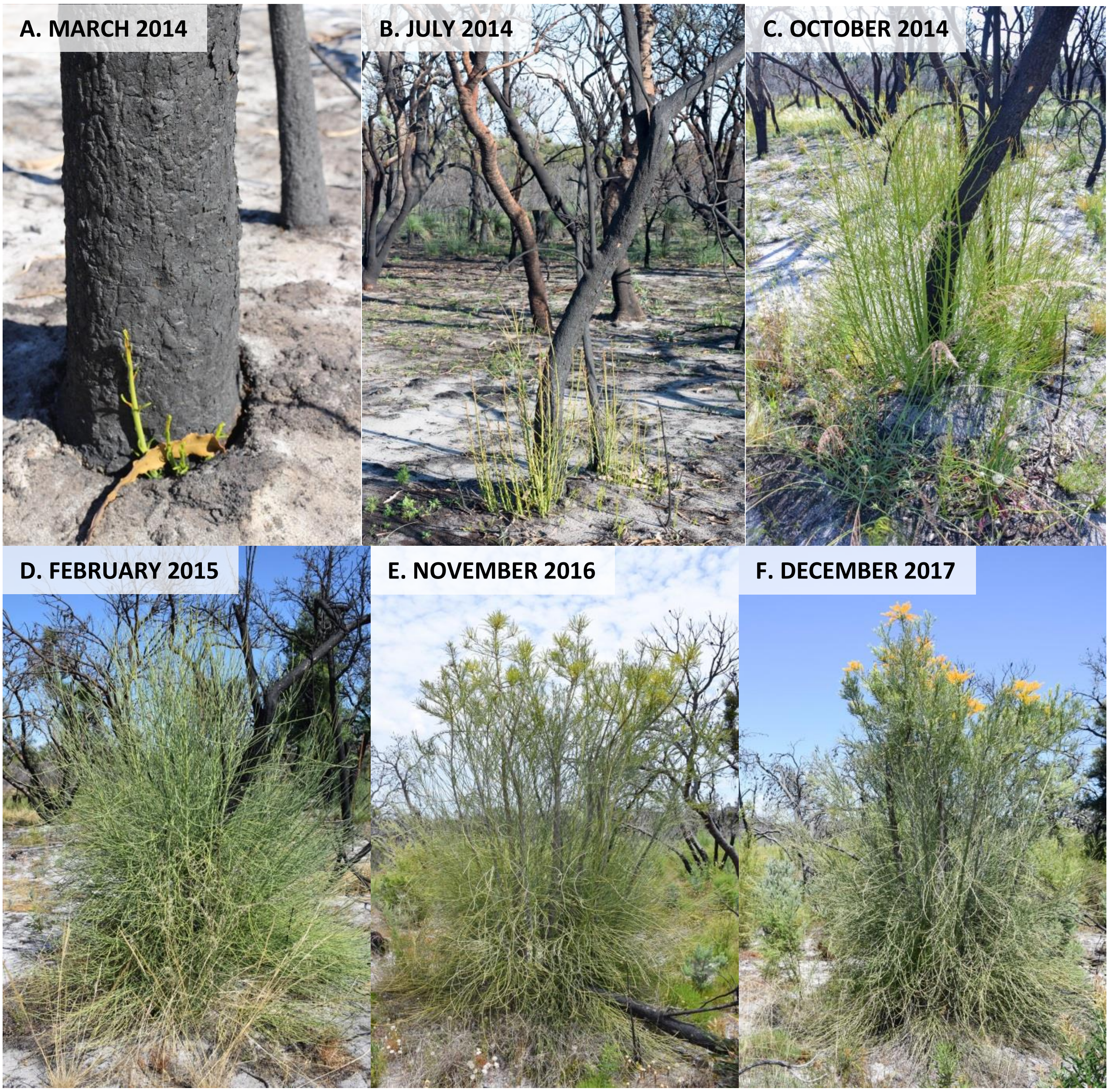


Figure 41. *Nuytsia floribunda* recovery after fire. Photos **A-C** show early regrowth from 1 month post fire (March 2014) to eight months post-fire (October 2014). **D.** Extensive regrowth one year post-fire. **E.** The old stem has collapsed and the plant is in bud. **F.** The first post-fire flowering in early summer 2017.

The results suggest that a mosaic of different fire ages should help to maintain high species richness in banksia woodland, due to the presence of both fire responsive and fire impacted species. However, fire-responsive plants that grow from seed stored in topsoil require sufficient time between fires to set seeds to replenish the soil seed bank. Plants that resprout after fire also require time to rebuild their canopy and replenish depleted reserves. In particular, banksias take years to regenerate a canopy after fire and may require several decades of growth before they are large enough to become resilient to fire. Thus, frequent hot fires will decrease tree cover in banksia woodland. More research is required to understand how long it takes individual species to recover after a fire and for canopy and soil seed banks to be replenished. A key initial finding of this study is that fire substantially promoted the diversity and relative dominance of weeds, especially without veldt grass control. Potentially the greatest concern to land managers after fire is the rapid invasion of serious new environmental weeds, such as eastern states eucalypts and tree tobacco.

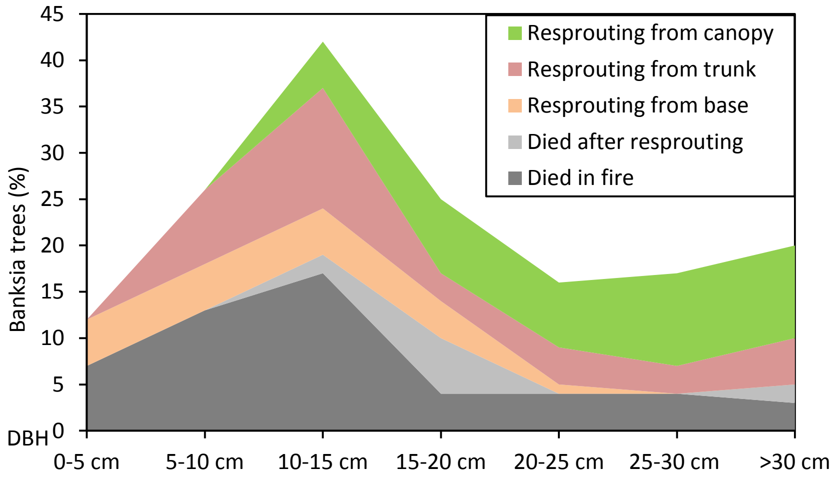


Figure 42. Recovery of *Banksia attenuata*, *B. menziesii* and *B. illicifolia* trees of difference size classes based on diameter at breast height (DBH) after the February 2014 fire at Shirley Balla Swamp, measured in four 25x25 m quadrats in 2015. Mortality was lower for trees over 20 cm in diameter. Overall, 33% of banksia trees were killed initially, 6% died after resprouting, 25% resprouted from the canopy, 23% resprouted from the trunk and 13% resprouted from the base only.

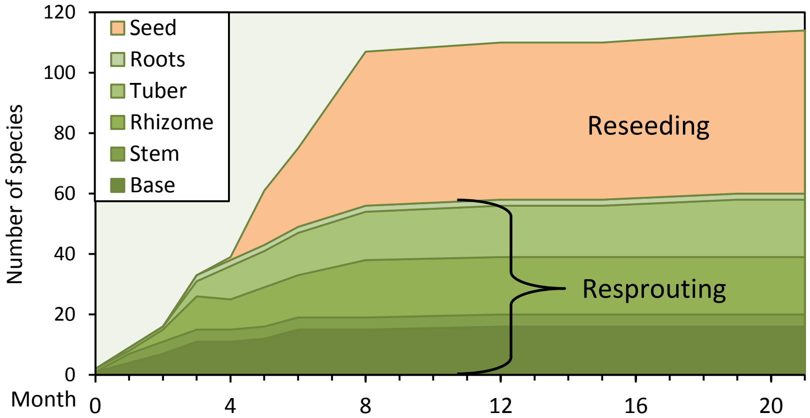


Figure 43. Changes in the relative diversity of native plants differing in regeneration strategies over the first 21 months after the fire. This graph shows the species richness of plants that germinated from seeds, or resprouted from roots, tubers, rhizomes, stems and bases. There were 50 reseeding and 60 resprouting species in total within seven 10x10 m monitoring plots.

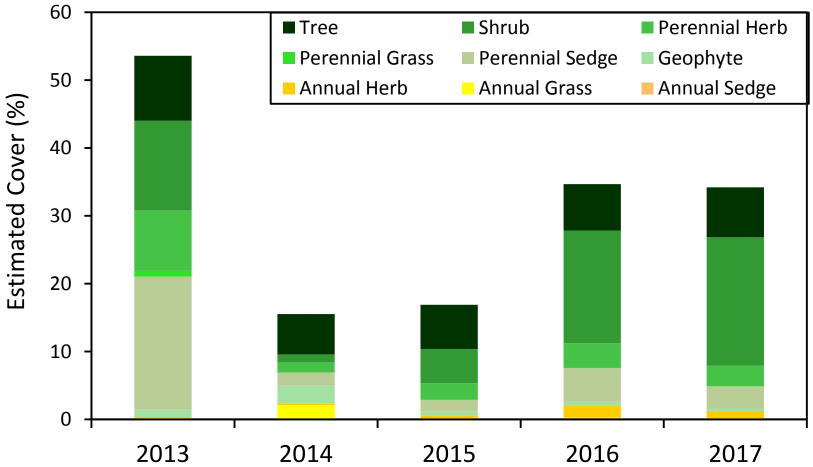


Figure 44. Changes in foliage cover for understory native species before (2013) and for four years after the February 2014 fire at Shirley Balla. Cover is estimated in three 10x10 m quadrats which were sprayed for veldt in 2013 and 2016. Perennial cover has increased after the fire but is not yet at pre-fire levels.

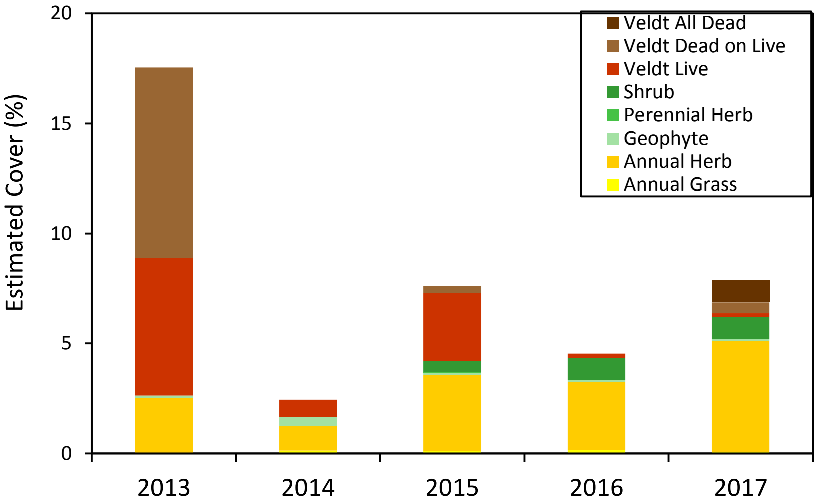


Figure 45. Changes in foliage cover for understory weed species before (2013) and for four years after the February 2014 fire at Shirley Balla. Cover is estimated in three 10x10 m quadrats which were sprayed for veldt in 2013 and 2016 only.

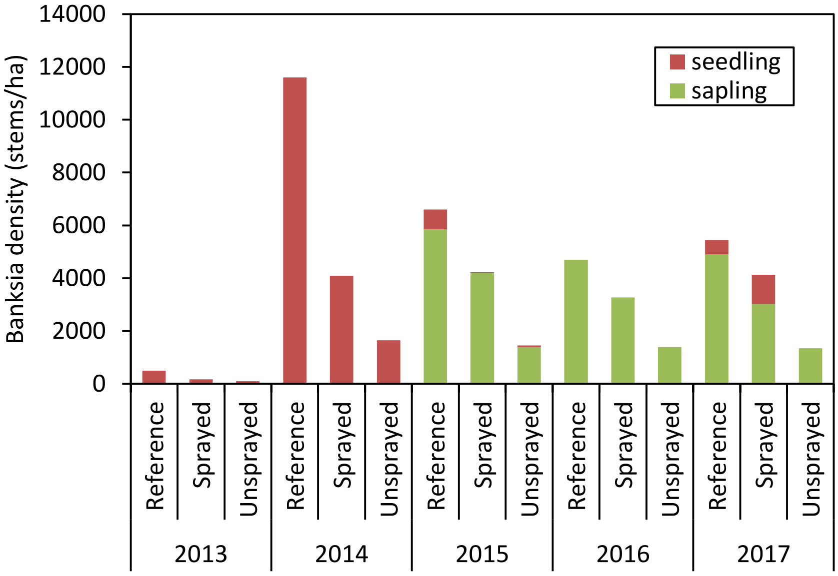


Figure 46. Banksia seed germination at Shirley Balla Swamp before (2013) and during the first four years following the fire in 2014. Most bars from 2014-2016 represent the 2014 (post fire) cohort, but red bars in 2017 resulted from new flowering and seed set of banksia trees which commenced in the 2016/17 summer. Seedlings from 2014 and 2015 are shown as saplings in later years. Banksia germinants were primarily *Banksia attenuata* and *B. menziesii*. These are average counts from seven 10x10 m quadrats.

Table 9. Plant diversity changes for native plants (green) and weeds (brown) resulting from the February 2014 fire in the seven 10x10 m quadrats at Shirley Balla.

Before the fire (2013) **122 species**		**After the fire (as at June 2017)** **160 species**	
110 native species	**12 weed species**	**119 native species**	**41 weed species**
4 native species were only recorded in plots before the fire: *Allocasuarina fraseriana* *Microlaena stipoides* *Microtis media* *Pelargonium littorale*	1 weed species was only recorded before the fire: *Sonchus asper*	13 new native species were recorded after the fire: *Aotus procumbens* *Calandrinia corrigioloides* *Cartonema philydroides* *Hemiandra pungens* *Ixiolaena viscosa* *Jacksonia gracillima* *Kennedia prostrata* *Lachnagrostis filiformis* *Macarthuria apetala* *Menkea australis* *Quinetia urvillei* *Senecio condylus* *Senecio* sp.	30 new weed species were recorded after the fire: *Acacia trigonophylla* *Aira caryophyllea/cupaniana group* *Aira praecox* *Arctotheca calendula* *Briza minor* *Carpobrotus edulis* *Cotula coronopifolia* *Echium plantagineum* weedy eastern states' *Eucalyptus* hybrid *Galium murale* *Gamochaeta calviceps* *Gamochaeta pensylvanica* *Geranium molle* *Lactuca serriola* *Lagurus ovatus* *Leontodon rhagadioloides* *Lotus subbiflorus* *Lysimachia arvensis* *Petrorhagia dubia* *Phytolacca octandra* *Poa annua* *Polycarpon tetraphyllum* *Rostraria cristata* *Rumex acetosella* *Sagina procumbens* *Solanum nigrum* *Symphyotrichum squamatum* *Trifolium campestre* *Urospermum picroides* *Vulpia* sp.

9. Monitoring Fauna in Restoration and Weed Management Sites

A fauna monitoring program occurred from 2012 to 2014 and is summarised in a separate report (Moore & Barrett 2013). As expected, bird species richness was higher in the reference sites than the restoration sites. Camera traps were also deployed and detected feral predators, reptiles and birds at all sites. For mammals, only the southern brown bandicoot and house mouse (*Mus musculus*) were captured. A total of 20 reptile species were captured with similar diversity in restoration and reference sites, but more individuals were detected in the reference sites. Six amphibian species were also captured, but only two of them were found in the restoration sites. Rapid Bushland Assessments are occurring in both restoration and some perennial veldt grass management sites to record fauna and habitat characteristics as part of a larger monitoring program across metropolitan habitats aimed at determining distribution, population changes and habitat condition for fauna. We have observed that pollinating insects are very common in our restoration sites (Fig. 24CD). In particular nectar scarab beetles, green spring beetles and European honeybees were abundant in the spring of 2016. Western bearded dragons have been observed mating in the restoration areas (Fig. 24E), and New Holland honeyeaters raising nestlings (Fig. 24F).

The BWR project also helped support the translocations of wallabies from Jandakot Airport to Harry Waring reserve. Brush wallabies have never been successfully translocated before. They are a secretive species that are difficult to capture and easily die from stress. In total 14 adult and 5 sub-adult brush wallabies were captured and relocated. As expected, they proved very difficult to capture. The translocation was a collaborative effort involving DBCA, Jandakot Airport Holdings, The University of Western Australia (UWA) and Murdoch University. Leticia Povh, a masters student from UWA carried out the monitoring from the wallabies released in October 2015 until the end of April 2016 and showed that many of them did survive. This project finished in 2016, but the department is committed to ongoing monitoring of this population.

Figure 47. Banksia Woodland Management Workshop audience and presenters. Close to 250 people attended to learn more about the latest research and management programs addressing the conservation of banksia woodland. Photo – Karen Clarke.

Figure 48. A post-workshop field trip gave attendees an opportunity to tour the department’s six-year-old restoration site at Anketell Road in Oakford. Seventy people attended and examined the results from the restoration techniques of topsoil transfer, planting and direct seeding. Shown is a successful area where all three techniques were used.

10. The Banksia Woodland Workshop

The Banksia Woodland Management Workshop in June 2017 was organised and run by staff of the Banksia Woodlands project and by Julia Cullity of Urban Nature (Figs. 47, 48, Table 10). The workshop brought together close to 250 people to hear about recent research and management programs focusing on protecting the values of banksia woodland and dealing with processes that threaten them. An ambitious program packed in 21 speakers on topics of floristic diversity, legislative status, restoration, fire ecology, weed management, dieback, groundwater, genetics and fauna and included case studies from the Parks and Wildlife Service and Botanic Gardens and Parks Authority of DBCA, university research, local government, consultants and community groups.

Table 10. Speakers and presentations delivered at the Banksia Woodland Management Workshop, June 2017.

Presenter	Title
Val English ***Parks and Wildlife Service***	The banksia woodlands of the Swan Coastal Plain Threatened Ecological Community (TEC)
Greg Keighery ***Parks and Wildlife Service***	Banksia woodlands: a ?uniquely Western Australian ecosystem
Mark Brundrett ***Parks and Wildlife Service***	Introducing the Banksia Woodland Restoration Project
Joe Fontaine **(authored by Pawel Waryszak)** ***Murdoch University***	Evaluating emergence, survival, and assembly of banksia woodland communities to achieve restoration objectives following topsoil transfer
Anna Wisolith ***Parks and Wildlife Service***	Using complementary methods to create banksia woodland: five years of progress
Vanda Longman ***Parks and Wildlife Service***	Banksia woodland rising from the ashes at Shirley Balla.
Karen Clarke **(authored by Karen Jackson et. al.)** ***Parks and Wildlife Service***	The war on weeds in banksia woodland
Elaine Davison ***Curtin University***	What is the long-term prognosis for dieback infested sites in banksia woodland?
Ray Froend ***Edith Cowan University***	Impacts of groundwater decline on banksia woodland
Alison Ritchie ***Botanic Gardens and Parks Authority***	Pollinators are vital for reconnecting banksia woodland remnants
Siegy Krauss ***Botanic Gardens and Parks Authority***	Seed sourcing for restoration of banksia woodland under climate change: insights from provenance trials
Ben Miller ***Botanic Gardens and Parks Authority***	Interactions between fire regimes and weed management in banksia woodlands
Linda Metz ***City of Cockburn***	Building resilience in disturbed banksia woodlands
Ruth Clark ***Waterbird Conservation Group***	Banksia woodland restoration on a small sandy rise at Maramanup
Erika Antal ***Banjup Residents Group***	Supporting endangered species on private land: Carnaby's cockatoo's food habitat creation in Banjup
Francis Smit & Alan Elliott ***SJ Landcare***	Dieback management on private property: a landholder's gamble
Lynda Smith ***Friends of The Spectacles***	Spectacular seedling success at The Spectacles
Mike Bamford ***Bamford Consulting Ecologists***	Fauna in a biodiversity hotspot: lessons from a sandpit
Christine Groom ***The University of Western Australia***	Urban foraging habitat for Carnaby's cockatoo
Geoff Barrett ***Parks and Wildlife Service***	Fauna monitoring in rehabilitated sites
Leonie Valentine ***The University of Western Australia***	Reintroduction of quenda in urban banksia woodlands

All presentations were recorded and can be watched separately on our YouTube channel at: youtube.com/playlist?list=PLwKOFN5-6PcSO_eSeuD7eFQDOF4SWgCr5 .

11. Conservation of Rare Orchids (*Caladenia huegelii* and *Drakaea elastica*)

Mark Brundrett, Margaret Collins and Karen Clarke worked closely with Andrew Crawford of the Threatened Flora Seed Centre and Anne Harris of Swan Region to undertake rare orchid surveys for the grand spider orchid (*Caladenia huegelii*) and glossy-leaved hammer orchid (*Drakaea elastica*) in 2017. Departmental staff were greatly assisted in these surveys by volunteers from the WA Native Orchid Study and Conservation Group over a total of 16 days of field work. Surveys were partly funded by other offsets and a grant from the Commonwealth Government's Threatened Species Strategy 30 plants by 2020 initiative. Permits for rare flora were obtained from DBCA to allow pollination and seed collection activities. Our 2017 work has resulted in a much better understanding of the size of several of the largest populations for both species. There were substantial threats to populations of both rare orchids, including high rates of grazing and low rates of pollination (Fig. 49).

The second main objective of these rare orchid conservation actions in 2017 was to collect seed for future translocations. We hand cross-pollinated flowers and fitted them with seed bags for protection during maturation. Hand pollination and seed bags are illustrated, along with seed processing in Figures 50 and 51. The majority of hand-pollinated plants set seed and in total 29 seed lots from the two species were placed in long-term storage at the Threatened Flora Seed Centre (Table 11). A small amount of seed from *Caladenia huegelii* was used for an *in-situ* germination trial in bushland adjacent to a reserve in 2017 and a second seed translocation is scheduled for April 2018. Artificial hand pollination was relatively easy and highly successful, and is recommended to augment natural seed set, especially for *Caladenia huegelii*, where natural pollination is extremely poor. Both of these orchids are extremely rare, and translocations of seeds or propagated seedlings are highly recommended both to augment existing populations and create new ones.

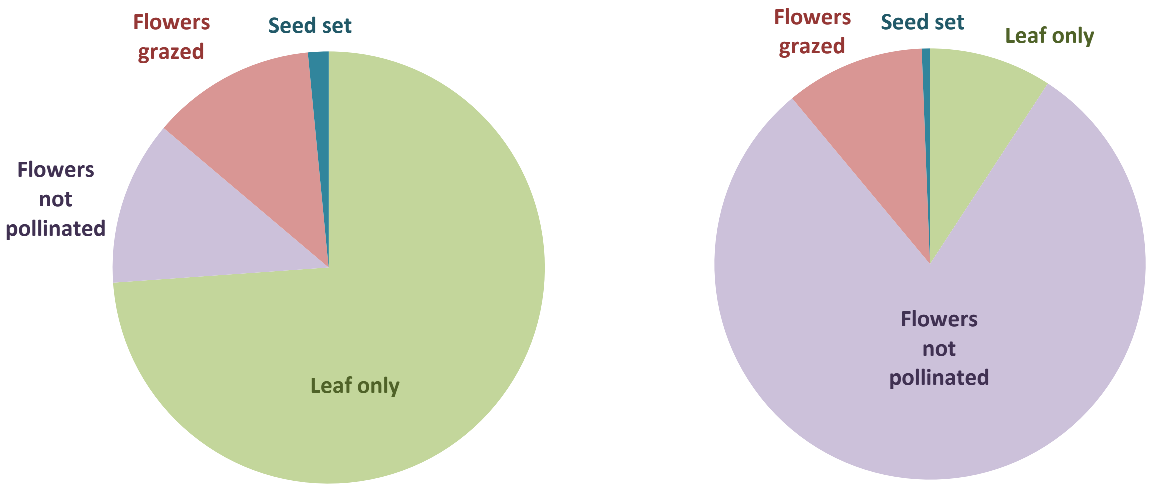


Figure 49. A. Flowering, pollination and grazing outcomes for *Drakaea elastica* in 2017 (1627 plants at three locations). **B.** Flowering outcomes for *Caladenia huegelii* in a large population in 2017 (187 plants).

Table 11. Collections of seed or rare orchids made in 2017 (stored at the TFSC).

Orchid	Populations	Locations	Seed bags	Seed pods
Caladenia huegelii	2	8	10	12
Drakaea elastica	4	16	19	20

Figure 50. Conservation of the grand spider orchid (*Caladenia huegelii*). Top row - flowers and habitat showing banksia tree dieback. Bottom row - counting plants and seed bag on hand pollinated flower.

Figure 51. Conservation of the glossy-leaved hammer orchid (*Drakaea elastica*). Top row - flower, grazing, burial by leaf litter and plants growing in a fire break. Middle row - cross pollination by hand. Bottom row - protecting pollinated flowers with seed bags and using cages for grazing protection.

12. Research Collaborations

The BWR project funded a PhD research project at Murdoch University to investigate seed germination from banksia woodland topsoil (Waryszak 2016). This research is summarised briefly in Section 4.3 and a paper is soon to be submitted. A BWR-funded project by Dr Elaine Davison at Curtin University investigated dieback resistance in banksia trees that were surviving in *Phytophthora cinnamomi* infested woodland. Invasion of the sapwood following inoculation with the pathogen (*Phytophthora cinnamomi*) was measured in the laboratory. This pathogen was isolated from all of the banksias tested, indicating that they were not highly resistant, but one tree was more resistant than the others (Davison et al. 2015). Additional research is required to investigate this further.

13. Project Management and Governance

The principal stakeholders for this project are the Commonwealth Department of the Environment and Energy, Jandakot Airport Holdings and DBCA. In addition to the Banksia Woodland Community Restoration Grants scheme, the BWR project has also developed partnerships with community groups and local governments to help manage banksia woodland areas as listed in Section 14. Major outcomes from the BWR project relative to objectives and tasks are briefly summarised in Table 12.

For most of 2017 the Project Management Group that oversees the BWR project consisted of DBCA's Swan Region Regional Manager (Stefan de Haan), Acting Regional Leader Nature Conservation (Steve Raper), Regional Ecologist (Geoff Barrett), District Manager (Craig Olejnik), Acting Manager Regional Parks Unit (Shawn Debono) and BWR Senior Ecologist (Mark Brundrett). Meetings are held every three to five months to organise finances, staffing, and collaborations with other organisations. Record keeping and quality control for this project follows standard protocols and requirements.

A Scientific Advisory Committee (SAC) was formed in 2011 to provide advice on scientific and management aspects of restoration programs such as the BWR project. Meetings were held every six to 12 months until 2014. The role of this committee has since been replaced by the Perth Urban Restoration Scientific Advisory Committee (PURSAC) established for the restoration of the Roe 8 corridor. PURSAC meets more frequently and includes the same members as the original SAC as well as many others.

Outcomes of the BWR project will also be presented in greater detail in a series of external reports and scientific papers which are listed in Appendix 1. Site specific internal reports detailing operations have also been developed for each of the areas where restoration or other management actions are occurring.

Table 12. BWR Project objectives and outcomes to December 2017.

Task	Objectives	Completed
I. Administration		
1. Filling Positions	Fill Senior Ecologist, Conservation Officer, Operations Officer, Survey Botanist roles	Operations and management positions filled
2. Project Management	Hold regular planning meetings to allocate budget and staff to tasks and roles	Regular project team and management team meetings
3. Meeting with Scientific Advisory Committee	Hold meetings to present outcomes and discuss objectives with scientific experts	Five meetings held from 2012 to 2014
II. Operations		
4. Selection of restoration sites	Choose best site(s) for topsoil-based banksia woodland restoration	Sites selected in 2011 following a comprehensive ranking process
5. Topsoil transfer process	Undertake urgent transfer of 18 ha of topsoil from Jandakot Airport Precinct 5	Soil transfer concluded in May 2012
6. Baseline data collection at JA and reference sites	Collect data for restoration site targets and CBC food value estimates	Data obtained for completion criteria, nursery orders and seed collection
7. Baseline vegetation data collection and monitoring	Measure weed and native cover data at restoration sites before topsoil transfer	Completed, but monitoring plant diversity and cover is ongoing
8. Restoration site preparation	Weedy topsoil and exotic tree removal, weed spraying, fencing etc. (20 ha)	Completed in 2012, but weed control and fencing repairs continue
9. Experimental design and setup at restoration sites	Targeted research trials established to optimize restoration of banksia woodland from topsoil seed banks, planted seedlings and direct seeding	1. Comprehensive data obtained ready for publication 2. PhD project at Murdoch University; completed with papers in preparation
10. Seed collecting, seed management and germination trials	Obtain seeds required for nursery orders and direct seeding and optimize germination by seed quality investigation	Seed collecting concluded in 2015. Banksia seed germination trials occurred in 2015 and 2016
11. Nursery seedlings and cuttings	Produce sufficient tubestock of banksia woodland plants for restoration sites	Planting and seeding was completed in 2016 for most areas
12. Direct seeding and planting native plants	Investigate effectiveness of direct seeding and planting for banksia woodland establishment	Direct seeding concluded in 2016 and monitoring is still underway
13. Site selection for weed control and other actions	Identify sites with highest priorities for weed control, etc. and allocate resources	Site visits and ranking process completed in May 2013
14. Actions to protect nature reserves from weeds	Control weeds in up to 500 ha with quality control assessment and follow-up spraying as required	Weed spraying in reserves has largely been successful, but requires follow-up management and monitoring
15. Controlling illegal site access	Fencing to protect banksia woodland from disturbance, weeds and *Phytophthora* dieback	Fencing works completed, but ongoing maintenance of sites continues
III. Research & collaborations		
16. Community Groups and Local Government	Manage high priority sites with community groups and local government	Grants scheme with $300,000 support for 20 community group projects in 19 locations
17. Banksia woodland monitoring program	Measure health of banksia woodlands in Perth using vegetation, groundwater and remote sensing data	Comprehensive monitoring and remote sensing program resulting in five years of data for 6 sites
18. Rare flora monitoring and management	Undertake surveys and manage habitats of rare orchids, especially *Caladenia huegelii*	Rare orchid surveys and translocations in 2017 are summarised in Section 11
19. Scientific research program	Research to measure and optimize plant and animal diversity in restoration sites	Banksia woodland monitoring after restoration, weed control or fire. Topsoil seedling germination and *Phytophthora* dieback research.
20. Communications	Provide information to community groups, the public and other stakeholders	Presentations for community groups, articles and press releases (see Section 10)

14. Communication and Outreach in 2017

14.1. Presentations

Talks for community groups and scientific conferences by Mark Brundrett or other project staff in 2017 are summarised below. Most of these are about the BWR project, but several concern related topics.

1. Four talks for the Banksia Woodland Management Workshop (16 June 2017, see Section 10).
2. Comparing approaches for restoring banksia woodland. Biological Sciences, The University of Western Australia (7 July 2017).
3. The global importance of mycorrhizas. International Conference on Mycorrhizas, Prague (3 August 2017).
4. Impacts of fire on native plants. Bush Foods Workshop (8 April 2017).
5. The root causes of plant diversity hotspots in Western Australia. Wildflower Society of WA (9 May 2017), Urban Bushland Council (10 July 2017), Naturalists Club of WA (March 21 2018), Royal Society of WA Symposium (27 July 2018).

14.2. Publications

Publications and reports for 2017 (others are listed in Appendix 1):

1. Keighery G, Longman V, Brundrett M. 2017. Weedy and natural distribution of *Acacia trigonophylla* (Fabaceae). *Western Australian Naturalist* 31 (1) 53-62.
2. Brundrett M, Collins M, Clarke K, Longman V, Wisolith A. 2017. *Flora and Vegetation Completion Criteria*. Department of Biodiversity, Conservation and Attractions, Perth.
3. Clarke K, Glossop B, Brundrett M, Collins M. 2017. *Site Selection for Topsoil Transfer and Management Actions*. Department of Biodiversity, Conservation and Attractions, Perth.

14.3. Partnerships and Consultation

The BWR project partnered the following groups in the following restoration/revegetation activities.

1. Project staff had a key role in PURSAC, especially concerning development of the restoration plan and species lists for the Roe 8 corridor project (Cockburn Community Wildlife Corridor). Membership of the Steering Committee to provide expert advice on restoration and provenance.
2. Greening Australia WA are joint managers of part of the Forrestdale Lake restoration site.
3. Friends of Forrestdale to plant tubestock, spread seed and monitor restoration areas.
4. Birdlife Australia provided volunteers for planting days in 2013 and 2014.
5. City of Cockburn received funding to manage weeds in Jandakot Regional Park.
6. Banjup Residents Group received seed for growing banksias to plant on private property which was burnt in the 2014 bushfire.
7. Regional Parks received flora and monitoring advice on the Eglinton Estates offset, the Roe Highway Extension project.
8. Advice and seed provided to support the Department of Biodiversity, Conservation and Attractions-managed Melaleuca Park, Dundas Road and Lowlands Restoration projects.
9. Western Australian Planning Commission (WAPC) received planting lists and flora advice for revegetation of a cleared WAPC lot at Harrisdale Swamp.
10. Friends of Upper Lesmurdie Falls received further flora advice for their restoration project in the Mundy Regional Park, above Lesmurdie Falls.
11. City of Armadale received planting lists for a sumpland at the Aspiri and Holland Park development adjoining Piara Nature Reserve.
12. Advice on the Bushmead Estate, Helena Valley Revegetation, Stream Restoration and Weed Management Plan.

15. Acknowledgements

Thank you to the following volunteers who kindly donated their time to help us with our work over the term of the project: Monique Anderson, Erika Antal, Tim Barling, Rebekah Bigaila, Zane Bingham, Annie Bone, Chloe Craig, Emily Cranstoun, Melissa Darling, Paige Featherstone, Stephanie Floeckner, Emma Frost, Eashani Haria, Mark Hutchison, Shaun Jackson, David James, Leah Knapp, Lizzy Longman, Katie McLellan, Kelli McCreery, Jemma Marris, Tim Morald, Sammy Norda, Kylie Payne, Nick Potter, Jim Prince, Xiubin Qi , Ellana Risk, Anya Robinson, Nick Suehrcke, Cate Tauss, Natasha Tay, Erich Volschenk, Debbie Walker, Graham Zemunik.

Planting volunteers:
Thank you to the following volunteers who kindly donated their time to help us with planting during the project: Carly Atkinson, Amanda Baker, Michael Baker, Steven Baker, Zane Bingham, Geraldine Box, Louise Corteen, Anita Downing, Renee Ettridge, Bryony Fremlin, Lauren Gleeson, Gordon Hansom, Vanessa Hill Leonard Hofert-Smith, Kelly Hutchison, Interchange Rockingham, Kathleen Jackson, David James, Tamara Kabat, Linda King, Jim Kirkham, Madeleine Kirkham, Pam Larson, David Mackenzie-Smith, Priya Mackenzie-Smith, Lorraine Marshall, Rob Mather, Sue Mather, Joy McGilvray, Malcolm McGilvray, Vanessa McGuiness, Ashlee Osborne, Jim Prince, Jacqui Purvis, Brad Reynolds, Paul Speering, Glen Speering, Leana Stendell, Matthew Stendell, Joseph Tan, Claire Taylor, Stan Telford, Margaret Telford, Brendan Trappe, Barbara Trappe, Debbie Walker, Kristel Wenziker, Adrian Wiley, Stephen Witherom, Anne Yardley, plus other unregistered volunteers.

Tree measuring:
Pieter Poot and 14 UWA students.

We also acknowledge the support and assistance of the following DBCA staff in the areas indicated:

Plant identification:
Russell Barrett (Botanic Gardens & Parks Authority), Una Bell, Kate Brown, Rob Davies, Malcolm French, Michael Hislop, Johan Hurter, Bronwen Keighery, Greg Keighery, Terry Macfarlane, Dean Nicolle, Grazyna Paczkowska, Juliet Wege

Regional Parks:
Evan Astbury, Robbie Campbell, Michael Cobby, Josh Cooper, Shawn Debono, John Harding, Glenn Jones, Daniella Miernik, Brad Newland, Zacc Phillips, Catherine Prideaux, Edie Wilson, Lyal Woods, Vince Woods

Seed collections managed by:
Anne Cochrane, Andrew Crawford, Simone Dudley, Anne Monaghan

Spatial information collection and processing:
Ricky van Dongen, Bart Huntley

Others
Kaye and Ron Levitt (donated Macrozamia seeds), Julia Cullity (weed mapping, spatial information & field work assistance, workshop organisation)

Workshop presenters
See Table 10.

16. References (see Appendix 1 also)

Davison EM, Speijers EJ, Tay FCS, Brundrett M, Wisolith AF. 2015. *Are banksias that survive on dieback sites resistant or disease escapes?* Final report, Curtin University and Department of Parks & Wildlife. April 2015

Department of Sustainability, Environment, Water, Population and Communities. 2010. Jandakot Airport Expansion, Commercial development and Clearance of Native Vegetation - EPBC 2009/4796. March 2010.

Department of the Environment. 2014. Variations in Conditions Attached to an Approval. Jandakot Airport Expansion, Commercial development and Clearance of Native vegetation - EPBC 2009/4796. April 2014.

Fowler WM, Fontaine JB, Enright NJ, Veber WP. 2015. Evaluating restoration potential of transferred topsoil. *Applied Vegetation Science* **18:** 379-390.

Jandakot Airport Holdings. 2010. *Jandakot Airport Offset Plan.* March 2010. Jandakot Airport Holdings Pty Ltd.

Local Biodiversity Program. 2013. 2013 Native Vegetation extent by Vegetation Complexes on the Swan Coastal Plain south of Moore River. Perth Urban Biodiversity Project. (url: pbp.walga.asn.au/Publications).

SER. 2004. SER Primer. Society for Ecological Restoration International (url: www.ser.org).

Waryszak P. 2016. Role of Environmental Filters in Restoration of Mediterranean-type Ecosystem of Banksia Woodland. Submitted PhD Thesis Murdoch University.

Western Australian Herbarium. 1998–. FloraBase—the Western Australian Flora. Department of Biodiversity, Conservation and Attractions, Perth. (url: florabase.dpaw.wa.gov.au/).

Annual Reports

Brundrett M, Longman V, Wisolith A, Jackson K and Clarke K. 2017. *Banksia Woodland Restoration Project Annual Report 5: January-December 2016.* Department of Parks and Wildlife, Crawley, Western Australia. January 2017.

Brundrett M, Longman V, Wisolith A, Moore T, Taylor K and Clarke K. 2016. *Banksia Woodland Restoration Project Annual Report 4: January-December 2015.* Department of Parks and Wildlife, Crawley, Western Australia. March 2016.

Brundrett M, Longman V, Wisolith A, Taylor K and Clarke K. 2015. *Banksia Woodland Restoration Project Annual Report 3: January-December 2014.* Department of Parks and Wildlife, Crawley, Western Australia. March 2015.

Brundrett M, Clarke K, Taylor K and Wisolith A. 2013. *Banksia Woodland Restoration Project Annual Report 2: December 2013.* Department of Parks and Wildlife, Crawley, Western Australia. December 2013.

Brundrett M. 2012. *Banksia Woodland Restoration Project Annual Report 1: July 2012.* Department of Environment and Conservation, Perth, Western Australia. July 2012.

Electronic Resources

Conservation Library	Reports produced by this project
Naturemap	Flora and vegetation data from this project
www.youtube.com/playlist?list=PLwKOFN5-6PcSO_eSeuD7eFQDOF4SWgCr5	Presentation for the Banksia Woodland Management Workshop, June 2017.
www.flickr.com/groups/banksia_plants	*Banksia Woodland Plants* (an interactive identification guide with 1400 images)
www.flickr.com/groups/perth_banksia_invert	Banksia Woodland Insects and other Invertebrates (400 images)

Appendix 1. Publications and Major Reports

Brundrett M. 2013. Creating New Flora and Fauna Habitats on the Swan Coastal Plain. *Bushland News*, Issue 85, Autumn 2013, p. 5.

Brundrett M. 2014. The Banksia Woodland Restoration Project. *Bushland News*, Issue 90, Winter 2014, p. 10.

Brundrett M. 2016. Using vital statistics and core habitat maps to manage critically endangered orchids in the West Australian wheatbelt. *Australian Journal of Botany* 64: 51-64.

Brundrett M. 2016. *Banksia Woodland Restoration Project.* Revegetation Industry Association of WA Seminar: Setting the Standards, 20-21 September 2016, Mount Claremont, Perth.

Brundrett M. 2016. *Translocation Proposal* Caladenia huegelii *within the Calleya Development in Banjup*. Department of Parks and Wildlife, Perth. Proposal approved 13 March 2017.

Brundrett M, Clarke K, Longman V. 2012. *Setting comprehensive and effective completion criteria for banksia woodland restoration.* Society for Ecological Restoration Australasia Conference, Perth.

Brundrett M, Clarke K and Longman V. 2014. Setting comprehensive and effective monitoring targets for banksia woodland restoration and management. In: Mucina L, Price JN & Kalwij JM (eds). *Biodiversity and Vegetation Patterns, Processes, Conservation.* Kwongan Foundation, Perth, Australia, p. 72.

Brundrett M, Collins, M, Clarke K. Longman V, Wisolith A. 2017. *Flora and Vegetation Completion Criteria.* Department of Biodiversity, Conservation and Attractions, Perth.

Brundrett MC, Grierson PF, Bennett LT, Weston CJ. 2017. Soils and below-ground interactions that shape Australian vegetation. In: *Australian Vegetation Second Edition*. Ed by: D. Keith. Cambridge University Press.

Brundrett M and Longman V. 2015. Recovery of banksia woodland after fire. *Wildflower Society of WA Newsletter*, May 2015, pp. 12-15.

Brundrett M and Longman V. 2016. Recovery of Banksia Woodland after Fire. *Western Wildlife (Land for Wildlife Newsletter)* 20: 10-12.

Brundrett M, Van Dongen R, Huntley B, Tay N, Longman, VA. 2018. A monitoring toolkit for banksia woodlands: Comparison of different scale methods to measure the recovery of vegetation after fire. *Remote Sensing in Ecology and Conservation*. (in press).

Clarke K, Glossop B, Brundrett M, Collins, M. 2017. *Site Selection for Topsoil Transfer and Management Actions.* Department of Biodiversity, Conservation and Attractions, Perth.

Collins M, Wisolith A, Brundrett M, Longman V, Jackson K and Clarke K. 2018. Banksia Woodland Restoration Project: Harrisdale Swamp Restoration Monitoring Results July - December 2017. Department of Biodiversity, Conservation and Attractions, Perth.

Davison EM, Speijers EJ, Tay FCS, Brundrett M, Wisolith AF. 2015. *Are banksias that survive on dieback sites resistant or disease escapes?* Final report. Curtin University and Department of Parks and Wildlife, Perth.

Dudley S, Crawford A, Cochrane A. 2014. *Annual Report 2013-2014: Seed Supply for the Banksia Woodland Restoration Project.* Threatened Flora Seed Centre, Department of Parks and Wildlife, Perth.

Keighery G, Longman V, Brundrett M. 2017. Weedy and natural distribution of *Acacia trigonophylla* (Fabaceae). *Western Australian Naturalist* 31: 53-62.

Longman V, Brundrett M, Clarke, K. 2016. Banksia Woodlands Restoration Project Flora Survey Quadrat Data 2011-2015. Metadata and data file. Department of Parks and Wildlife, Crawley, Western Australia NatureMap website (url: naturemap.dpaw.wa.gov.au).

Moore T, and Barrett G. 2013. *Banksia Woodlands Restoration Project: Fauna monitoring and milestones*. Draft internal report. Department of Parks and Wildlife, Perth.

Taylor K. 2014. Controlling Dolichos pea (*Dipogon lignosus*) at Harrisdale Swamp. *Bushland News*, Issue 91, Spring 2014, p. 3.

Wisolith A. 2016. Five years of restoring banksia woodland. *Bushland News*, Issue 100, Summer 2016-2017, p. 10.

Appendix 2. Native Plant Species Present in Restoration Areas

Plants present in revegetated sites in the first six years after establishment (2012-2017). Species are derived from the topsoil seed bank, spread from local areas (local opportunist), or from inclusion in planting and seeding lists (total 162).

Species	Topsoil	Topsoil and other	Direct Seeded	Planted 2012 -2015	Local Opportunist	Dampland only	First flowering
Acacia huegelii	1			1			2014
Acacia pulchella	1			1			2014
Acacia saligna	1			1			2016
Acacia stenoptera	1						2015
Adenanthos cygnorum	1						2015
Allocasuarina fraseriana			1	1			
Allocasuarina humilis			1	1			2016
Amphipogon turbinatus	1	1	1	1			2014
Anigozanthos humilis	1	1	1				2013
Anigozanthos manglesii	1	1	1	1			2012
Aotus procumbens	1			1	1		2013
Arnocrinum preissii	1						2013
Austrostipa compressa	1	1	1		1		2012
Austrostipa macalpinei					1		2014
Babingtonia camphorosmae			1				2015
Banksia attenuata	rare		1	1			2016
Banksia ilicifolia			1	1			2016
Banksia menziesii			1	1			2015
Beaufortia elegans				1		1	
Boronia ramosa	1						2013
Bossiaea eriocarpa	1	1	1	1			2014
Brachyloma preissii	1			1			2014
Burchardia congesta	1	1	1				2014
Caladenia flava	1						2014
Calandrinia corrigioloides	1						2013
Calandrinia granulifera	1						2013
Calothamnus lateralis				1		1	2017
Calytrix angulata				1			2013
Calytrix fraseri				1			2014
Cartonema philydroides	1				1		2012
Cassytha flava	1				1		2015
Centrolepis drummondiana	1						2012
Centrolepis inconspicua	1						2013
Chamaescilla corymbosa	1						2013
Comesperma calymega	1						2013
Conostephium pendulum	1						2016
Conostylis aculeata			1	1			2014
Conostylis juncea	1						2014
Conostylis setigera	1			1			2014
Corymbia calophylla			1	1		1	
Corynotheca micrantha	1						2015
Crassula colorata	1						2012
Crassula decumbens	1						2013
Croninia kingiana	1						2014
Dampiera linearis	1			1			2013
Dasypogon bromeliifolius	1	1	1	1			2013
Daucus glochidiatus	1						2014
Daviesia physodes	1						2016
Daviesia triflora	1						2017
Desmocladus flexuosus	1			1			
Dianella revoluta				1			
Dichopogon capillipes				1			2017
Diuris corymbosa	1						2014
Drosera erythrorhiza	1						2016
Drosera glanduligera	1						2012
Drosera macrantha	1						2013
Drosera paleacea	1						2015
Epilobium hirtigerum					1		2013
Eremaea asterocarpa			1	1			2013
Eremaea pauciflora	1		1	1			2015

Species	Topsoil	Topsoil and other	Direct Seeded	Planted 2012 -2015	Local Opportunist	Dampland only	First flowering
Eucalyptus marginata			1	1			2016
Eucalyptus rudis				1	1	1	2017
Eucalyptus todtiana			1	1			2017
Exocarpos sparteus					1		2012
Gastrolobium capitatum	1	1	1				2014
Gnephosis angianthoides	1						2012
Gompholobium tomentosum	1	1	1	1			2013
Gonocarpus pithyoides	1						2013
Haemodorum spicatum	1	1	1				2013
Hakea prostrata			1				2015
Hardenbergia comptoniana	1				1		2016
Hemiandra pungens	1			1	1		2013
Hemiandra sp. Jurien				1			2016
Hensmania turbinata	1						2014
Hibbertia huegelii/sericostachya	1		1	1			2013
Hibbertia hypericoides	1			1			2013
Hibbertia racemosa				1			2014
Hibbertia subvaginata	1			1			2012
Homalosciadium homalocarpum	1						2012
Hovea trisperma	1						2013
Hyalosperma cotula	1						2013
Hypocalymma angustifolium	1	1	1	1			2014
Hypocalymma robustum	1						2014
Hypolaena exsulca	1						2015
Isolepis marginata	1				1		2012
Jacksonia furcellata	1	1	1	1	1		2014
Jacksonia gracillima	1						2015
Jacksonia sternbergiana	1						2014
Juncus pallidus					1	1	2012
Kennedia prostrata	1			1			2013
Kunzea glabrescens	1			1	1		2015
Laxmannia ramosa	1						2013
Laxmannia squarrosa	1						2013
Lechenaultia floribunda	1			1	1		2013
Lepidosperma sp.				1			2014
Lepidosperma squamatum	1			1			2013
Leptomeria empetriformis	1						2016
Leucopogon conostephioides	1						2013
Levenhookia stipitata	1						2012
Lobelia tenuior	1				1		2012
Lomandra caespitosa	1			1			2014
Lomandra hermaphrodita	1			1			
Lomandra nigricans				1			
Lomandra preissii				1			
Lomandra suaveolens	1			1			2014
Lyginia barbata/imberbis	1			1			2015
Macarthuria apetala	1						2015
Macarthuria australis	1		1		1		2012
Macrozamia fraseri			1				
Melaleuca incana subsp. *nana*				1		1	2016
Melaleuca preissiana				1		1	2015
Melaleuca rhaphiophylla				1		1	2017
Melaleuca seriata			1	1			2013
Melaleuca teretifolia				1		1	
Melaleuca thymoides	1	1	1	1			2015
Melaleuca viminea				1		1	
Microtis media					1		2013
Millotia tenuifolia	1						2013
Nuytsia floribunda			1	1			
Orthrosanthus laxus				1			
Patersonia occidentalis	1	1	1				2013
Pericalymma ellipticum				1		1	2017
Persoonia saccata	1						2016
Petrophile linearis			1	1			2015

Species	Topsoil	Topsoil and other	Direct Seeded	Planted 2012 -2015	Local Opportunist	Dampland only	First flowering
Phlebocarya ciliata	1			1			2016
Phlebocarya filifolia				1			2017
Phyllangium paradoxum	1						2012
Phyllanthus calycinus	1						2013
Philotheca spicata	1						2016
Platysace filiformis	1						2013
Podotheca angustifolia					1		2013
Podotheca gnaphalioides	1				1		2012
Poranthera microphylla	1						2012
Poranthera moorokatta	1						2012
Poranthera huegelii	1						2017
Pultenaea reticulata			1			1	2016
Quinetia urvillei	1						2012
Regelia ciliata				1		1	2015
Regelia inops				1			2015
Rhodanthe citrina	1						2012
Scaevola repens	1						2015
Schoenus curvifolius	1			1			2014
Schoenus caespititius	1			1			2014
Scholtzia involucrata	1		1	1			2014
Senecio condylus					1		2013
Siloxerus humifusus	1				1		2012
Sowerbaea laxiflora	1						
Stirlingia latifolia	1	1	1	1			2015
Stylidium araeophyllum	1						2013
Stylidium piliferum	1						2013
Stylidium repens	1						2015
Synaphea spinulosa	1						2014
Thysanotus arbuscula	1						2014
Thysanotus manglesianus (sp. climbing)	1						2015
Thysanotus arenarius	1						2016
Thysanotus sparteus	1						2016
Thysanotus thyrsoideus	1						2013
Trachymene pilosa	1						2012
Tricoryne tenella	1						
Wahlenbergia preissii	1						2013
Xanthorrhoea preissii			1	1			
Xanthosia huegelii	1						2013
TOTAL	**115**	**15**	**37**	**69**	**22**	**13**