Banksia Woodland Restoration Project

Annual Report 5

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Abbreviations

- BWR – Banksia Woodland Restoration Project (this project)
- CBC - Carnaby's cockatoo, Carnaby's black cockatoo (*Calyptorhynchus latirostris*)
- Completion Criteria – numeric targets or milestones for restoration projects used to report outcomes.
- DEC – the former Department of Environment and Conservation, now the Department of Parks and Wildlife
- JAH – Jandakot Airport Holdings Pty Ltd
- 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).
- SCP – Swan Coastal Plain
- TEC – Threatened Ecological Community
- TFSC - Threatened Flora Seed Centre (Department of Parks and Wildlife, Kensington)

Executive Summary

The Banksia Woodland Restoration (BWR) Project is managed by the Department of Parks and Wildlife 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. 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 hectares 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 Parks and Wildlife with funding of $9,200,000 for "rehabilitation and conservation activities in banksia woodland within 45 km of the airport".

In 2014, the Commonwealth amended the ministerial conditions relating to this offset removing the five-year deadline to complete payment of offset funding to Parks and Wildlife (EPBC 2009/4796, Department of the Environment 2014). This created uncertainty about completion of project objectives and temporarily disbanded the BWR's specialist restoration team. In September 2015, partial funding associated with 14 ha of clearing at Jandakot Airport was received by Parks and Wildlife. This allowed the project to be funded until September 2016. In July 2016, the Department of the Environment and Energy audited the offset, at which time JAH confirmed they were committed to payment of the full $9.2 million to Parks and Wildlife and that they were close to finalising the next phase of clearing. In August 2016, payment of another $2.3 million was received from JAH. In total 96% of the funding has been received, with over $300,000 outstanding.

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 five years include:

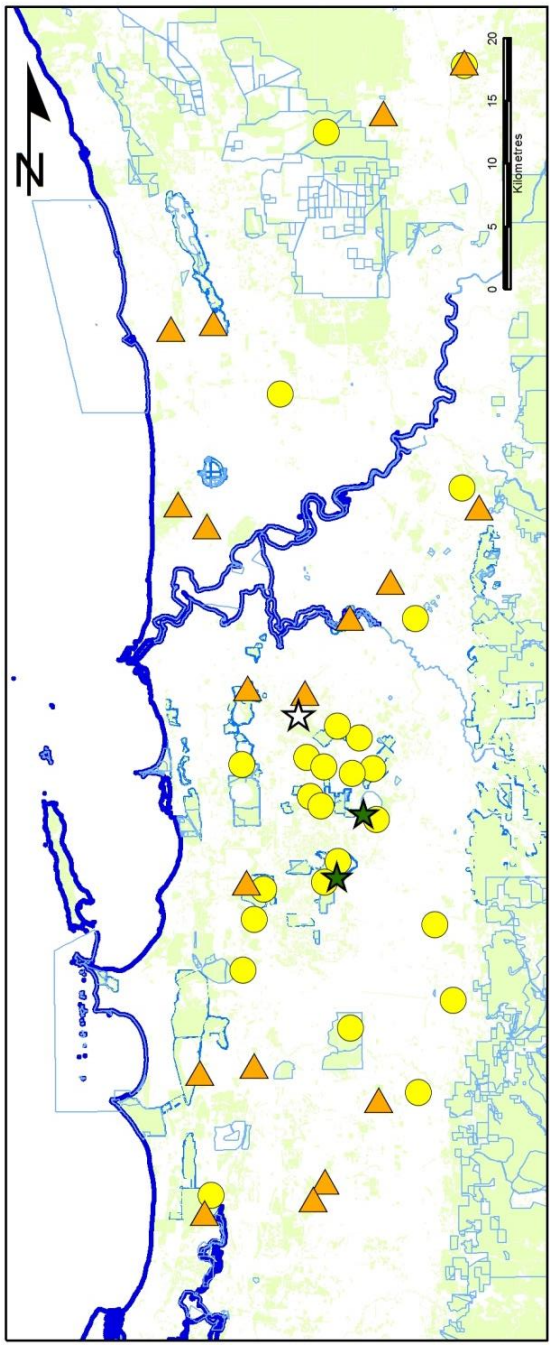
1. Selection of restoration sites using a comprehensive prioritisation process based on the objectives of the project.
2. Establishment of 50 ha of new banksia woodland on cleared sites using various combinations of topsoil transfer, direct seeding and/or planting of seedlings. Of this, a total of 16 ha received topsoil directly transferred from Jandakot Airport.
3. Management of threatening processes in existing banksia woodland to protect habitat and improve vegetation condition by (locations shown in the Map below):
    a. Control of the most serious environmental weeds in over 600 ha of bushland.
    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 bushfire.
5. Providing funding, seeds, seedlings and advice to community groups and local governments for banksia woodland restoration at 20 locations.
6. Enhancing conservation of the grand spider orchid (*Caladenia huegelii*) through translocations and surveys.

The main aim of restoration work is to establish native vegetation that is self-sustaining and requires minimal management in the long term. Two sites with a total area of 50 ha were selected for restoration of banksia woodland in completely degraded areas dominated by weeds at Forrestdale Lake and Anketell Road Bushland in Jandakot Regional Park (see Table). Flora surveys of reference sites provided data on plant diversity and density which was used to set targets for evaluating restoration success, as well as to plan seed collection and nursery orders. These reference sites were established at Jandakot Airport (where the topsoil was sourced) and areas close to the restoration sites at the beginning of the project.

The BWR project worked with the Parks and Wildlife Threatened Flora Seed Centre to manage seed collections and undertake research to resolve problems with seed germination for some species. A major seed resource has been established with over 1200 seed batches from 122 species, of which 341 batches were sent to nurseries, 318 batches were used in direct seeding, and 167 batches were provided to other restoration projects or community groups.

Restoration at Anketell Road and Forrestdale Lake included 16 ha of topsoil transfer in April-May 2012, and 40 ha of planting of nursery-raised seedlings from 2012 to 2015 (see Table below). In total, more than 46,000 nursery-raised local provenance native seedlings were planted. There was a further 15 ha of direct seeding with the support of Greening Australia (WA) in 2012, 2014 and 2016, as well as 11 ha of hand direct seeding in 2016.

In total 159 species of native plants grew in the restoration sites, of which 114 came from the topsoil seed bank while the remaining species were introduced by planting and direct seeding. At both major restoration sites, native plant growth from topsoil peaked at over 700,000 stems per hectare in 2013, and then declined substantially following several extremely hot and dry summers. There was an average of 18,000 stems per ha of native perennials by late 2016. Plant density in restoration monitoring plots had reached targets in about 70% of areas with topsoil (16 ha) prior to the summer of 2016/2017. Targets for the density of Carnaby's cockatoo food plants, in particular *Banksia attenuata* and *B. menziesii*, were also reached in most areas. However, areas established by direct seeding and planting in 2014 still have relatively low plant density and cover (15 ha) and may require further planting or seeding to reach targets. Perennial native plant cover in areas with topsoil increased gradually each year and average cover surpassed 10% in 2016 (see Graph). Annual native plants and weeds were initially dominant in both cover and density in restoration areas, but perennial weed cover decreased substantially over time because of weed control.

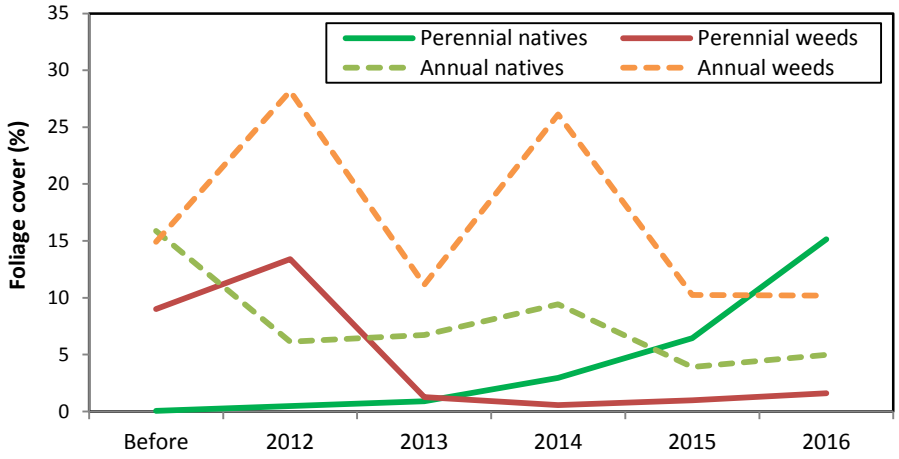


Map showing *Banksia Woodland Restoration Project locations in the Perth Metropolitan Region relative to Jandakot Airport (white star). These include two major restoration areas (green stars), sites for weed management (yellow circles), and funding provided to community groups for the restoration or repair of banksia woodlands (orange triangles). This map also shows remnant vegetation (light green shading) and reserves managed by the Department of Parks and Wildlife (light blue boundaries).*

By late 2016 completion criteria targets for the density and diversity of trees and understory plants in restoration areas were attained in about 70% of areas with topsoil (16 ha). However, areas without topsoil that were direct seeded in 2014 and 2016 require further management to control weeds (17 ha). Monitoring will need to continue in the future to ensure a self-sustaining ecosystem develops, determine which restoration methods are successful and inform future management. Additional monitoring is also required to determine the relative cost effectiveness of different methods for restoration and the overall cost of establishing banksia woodland with a diverse understory and sufficient banksia trees in the canopy.

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 five years at the largest restoration site, Anketell Road. The increase in perennial native plants is a result of seed germination and planting, while the reduction in perennial weeds is due to herbicide spraying. Note: The cover of annual natives and weeds is partly determined by rainfall.*

The second major component of the BWR project is to undertake management to improve the condition of existing banksia woodland in the conservation estate. In total, over 600 ha in 23 reserves were sprayed for perennial veldt grass (*Ehrharta calycina*) and other major environmental weeds (see Map). These sites were selected as the best condition banksia woodland under greatest threat after mapping weeds in 23 reserves (1400 ha). Weed control using selective herbicides occurred at 20 locations in 2013 and 2014 (approx. 600 ha). Unfortunately, only 120 ha could be sprayed for weeds in 2016 due to funding interruptions, and there was increased perennial veldt grass cover at some sites. Offset funding was also used to establish a community grants program, the Perth Banksia Woodland Community Restoration Grants, which has provided $300,000 for restoration, weed management or dieback control at 20 locations (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, but perennial native plants are also responding and will be quantified by monitoring in 2017. 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 the 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). More plant species recovered by seed germination rather than by resprouting, but the latter resulted in greater cover and major benefits to weed management were measured post-fire.

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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 is the payment of $9,200,000 to The Department of Parks and Wildlife (formerly DEC) 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 were described in previous annual reports. 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

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, the Commonwealth amended the ministerial conditions for the offset authorizing a variation to approval EPCB 2009/4796 (Department of the Environment 2014). This allowed JAH to postpone payments to Parks and Wildlife until clearing occurred, rather than make annual payments from 2010-2015 as agreed under the original schedule with a 5-year finalisation limit (Department of the Environment 2014). For Parks and Wildlife, the unexpected delays in funding relative to the previously agreed schedule directly affected the continuity, scheduling and resourcing of the BWR project in 2015 and 2016. In particular, there was uncertainty about completion of project objectives and temporarily disbanded the BWR's specialist restoration team. A relatively small area of Jandakot Airport (14 ha) was cleared in 2015, resulting in an interim payment to Parks and Wildlife in August that allowed re-employment of key staff and some restoration activities to continue in 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 Parks and Wildlife. Parks and Wildlife advised that full or partial payment was required before the end of September 2016 for the Banksia Woodland Restoration Project to continue and allow key objectives under Condition 4b of EPCB 2009/4796 to be achieved.

In August 2016, the board of JAH gave the authorisation for a payment of $2.3 million to be made to Parks and Wildlife. This allowed the specialist restoration team to be retained and ongoing restoration works to be continued. However, the delays and changes to funding have already affected project outcomes significantly. To date, 96% of the agreed funding has been received. A total of $383,333 remains outstanding associated with the final seven ha of clearing at Jandakot Airport. Timing of this payment is under negotiation with JAH.

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. Therefore, the BWR project set up a collaboration with Parks and Wildlife'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. Trials by the TFSC have been done on various species, including banksias, to test the temperature requirements for germination. 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 52 other locations (Table 1). After four years of seed collection, 1261 seed batches from 151 species have been quantified. Germination testing of 613 batches from 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. This year 194 seed batches have been moved into long-term freezer storage, and in total 1044 batches are in freezer storage where they will remain available for use by restoration projects. Over the life of the project, around 6.4 kg of seed from 49 species have been sent to nurseries (Table 2), and over 45 kg from 79 species have been used for direct seeding (e.g. Table 3).

Table 1: Seed inputs and outputs at the TFSC for the BWR project from 2011-2017, including seed quantified and germination tested, as well as seed placed into long-term freezer storage.

	TOTAL 2011-2017	
	Number of Batches	**Number of Species**
Received	1212	122
Quantified	1261	151
Germinated	613	87
Nursery orders	341	49
Direct seeding orders	517	79
Seed given to other projects	167	59
Long-term freezer storage	1044	170

Table 2. 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	Total
2012	2867	2252	-	5119
2013	8287	4425	175	12,712
2014	12,136	5256	467	17,392
2015	9474	1337	425	11,236
GRAND TOTAL	**32,764**	**13,270**	**1067**	**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 1440 *Banksia attenuata* seeds were planted across four plots at Anketell Road. Half of the seeds were pre-soaked in water, while the other half was untreated (control). In addition, two seeding times (June and July) were compared. In 2016 the trial was repeated using the same methods but using earlier seeding times (May and June) (Fig. 1).

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). However, despite the 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. By March 2017 (44 weeks after seeding), average survival of seedlings across all treatments was only 2% for the 2016 trial (see Fig. 1), with similarly low survival from the 2015 trial. These trials occurred in four areas with very low plant density at Anketell Road, possibly indicating an unknown problem with these areas, though previous results from other small trials suggest that such low survival of banksias is fairly typical of the site.

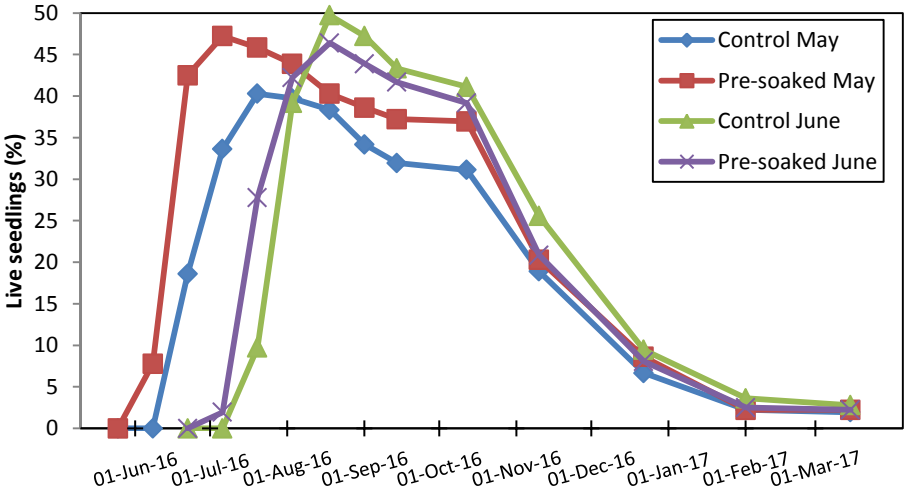

Figure 1. Survival results from the 2016 banksia seed germination trial. Two planting times, May and June were used, at four weeks apart. Despite quicker emergence times for the pre-soaked seeds, both the pre-soaked and control (untreated) *Banksia attenuata* seeds died off at similar rates. Survival after 44 weeks was only 2% for all treatment/timing combinations.

Table 3. List of species and amounts of seed (g) used for direct seeding in 2016 (totals for each site exclude *Macrozamia*).

Species	Anketell Road machine direct seeded	Anketell Road hand direct seeded	Forrestdale Lake hand direct seeded	Total
Acacia huegelii	10.0	30.0	6.3	46.3
Acacia pulchella	63.8	216.3	30.0	310.0
Acacia saligna	5.0	15.7	30.0	50.7
Adenanthos obovatus	4.5	16.0	na	20.5
Allocasuarina fraseriana	5.0	10.4	na	15.4
Allocasuarina humilis	60.0	222.5	48.0	330.5
Amphipogon turbinatus	34.5	83.5	6.3	124.3
Anigozanthos manglesii	na	28.0	33.0	61.0
Astartea scoparia	2.0	7.9	na	9.9
Austrostipa compressa	19.0	65.2	10.4	94.6
Banksia attenuata	1291.5	1385.6	202.4	2879.5
Banksia ilicifolia	81.5	97.3	9.7	188.5
Banksia menziesii	677.5	859.7	120.0	1657.2
Beaufortia elegans	3.0	9.0	12.0	24.0
Brachyloma preissii	20.1	60.0	na	80.1
Burchardia congesta	21.5	73.4	12.0	106.9
Calothamnus lateralis	na	7.8	na	7.8
Calytrix fraseri	1.0	1.1	na	2.1
Chamaescilla corymbosa	1.8	11.5	na	13.3
Conostylis aculeata	8.0	19.1	30.0	57.1
Conostylis juncea	na	0.1	na	0.1
Conostylis setigera	na	0.03	na	0.03
Croninia kingiana	18.0	52.8	na	70.8
Dasypogon bromeliifolius	70.0	215.1	2.6	287.7
Eremaea asterocarpa	5.5	26.7	34.5	66.7
Eremaea pauciflora	81.0	244.9	1.2	327.1
Eucalyptus marginata	45.0	87.6	15.0	147.6
Eucalyptus todtiana	10.0	11.1	15.0	36.1
Gastrolobium capitatum	13.0	37.0	na	50.0
Gompholobium tomentosum	1.0	3.4	na	4.4
Haemodorum spicatum	0.5	0.8	na	1.3
Hemiandra pungens	3.0	10.6	na	13.6
Hibbertia subvaginata	3.0	9.7	na	12.7
Hovea trisperma	na	0.9	na	0.9
Jacksonia furcellata	na	2.7	na	2.7
Kennedia prostrata	1.5	6.0	na	7.5
Lechenaultia floribunda	3.5	14.0	na	17.5
Lomandra caespitosa	0.01	na	na	0.01
Lyginia barbata	na	1.8	na	1.8
Macrozamia preissii	na	22000.0	approx. 8000	approx. 30000
Melaleuca preissiana	4.5	6.5	6.0	17.0
Melaleuca seriata	5.0	16.9	6.0	27.9
Melaleuca thymoides	5.0	17.1	6.0	28.1
Nuytsia floribunda	152.0	273.0	93.0	518.0
Patersonia occidentalis	1.5	4.7	na	6.2
Pericalymma ellipticum	2.2	8.2	na	10.4
Persoonia saccata	1428.0	4247.4	na	5675.4
Petrophile linearis	na	2.0	na	2.0
Philotheca spicata	0.8	2.9	na	3.8
Podotheca gnaphalioides	8.0	29.5	16.4	53.9
Regelia ciliata	1.0	6.6	na	7.6
Regelia inops	na	na	6.2	6.2
Scholtzia involucrata	122.5	399.7	5.6	527.8
Stirlingia latifolia	1.0	2.0	na	3.0
Stylidium brunonianum	na	0.2	na	0.2
Thysanotus patersonii	na	0.9	na	0.9
Xanthorrhoea preissii	78.5	268.2	19.4	366.1
TOTAL (g)	**2097.3**	**6123.9**	**269.0**	**8490.2**

3. Restoring Banksia Woodland using Topsoil Transfer and Planting

Figures 2 and 3 show the extent of restoration works at Anketell Road and Forrestdale Lake between 2012 and 2015. All seeded and planted species are listed in Appendix 2. 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, as well as most of the planted areas (Figs. 2, 3).

Topsoil from Jandakot Airport was spread to a uniform depth of either 50 or 100 mm in April-May 2012 at both Anketell Road and Forrestdale Lake, after a thin layer of existing topsoil was scraped off to reduce the weed soil seed bank. Planting and direct seeding was started in 2012 with larger planting and seeding programs from 2013 to 2015, as described in 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 (Clarke *et al.* 2017). Topsoil from Jandakot Airport was only applied to upland areas, as it contained seeds of species unsuited to dampland habitats.

A total of over 46,000 plants were planted over four years (2012-2015) at Anketell Road and Forrestdale Lake (see Table 2). Nursery orders primarily consisted of trees and shrubs with canopy stored seed that were unlikely to regenerate from topsoil. Species and quantities for planting were based on data from reference sites and later from monitoring of the restoration sites to ensure the sites were approaching completion criteria targets. Tubestock was planted by Parks and Wildlife staff, 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 consolidate a larger area of banksia woodland (Figs. 2, 3). No planting was undertaken in 2016 because of the delays in funding.

Work to manage weeds in restoration sites is ongoing, with perennial species targeted because of their invasiveness and competitive ability. Perennial veldt grass was sprayed using a grass-selective herbicide from 2012 to 2014. There was a substantial increase in weed cover due to funding issues in 2015, but most of the areas were sprayed again in 2016. Other invasive weeds (all bulbs, *Euphorbia, Pelargonium*, *Carpobrotus*, *Lupinus,* etc.) were removed by hand each year including 2016. Now that funding for this project has continued, it is anticipated that several more years of weed control should be sufficient to control major weeds at these sites.

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	2012	10	3.5	13.5
	2014	13	-	13
	TOTAL	23	3.5	26.5
Total for all activities		**39**	**11**	**50**

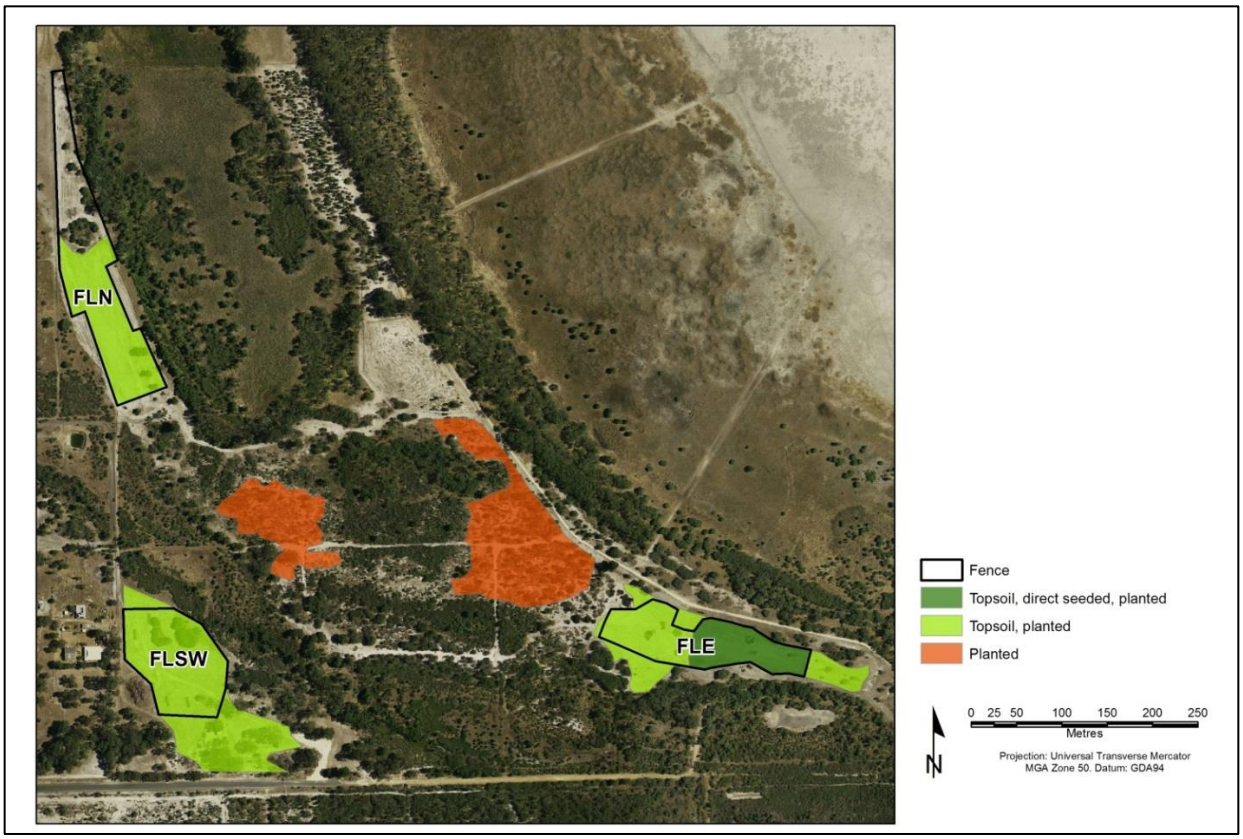

Figure 2. Forrestdale Lake restoration site showing total areas fenced, direct seeded and planted from 2012 to 2016. Three separate management areas with respread topsoil are labelled.

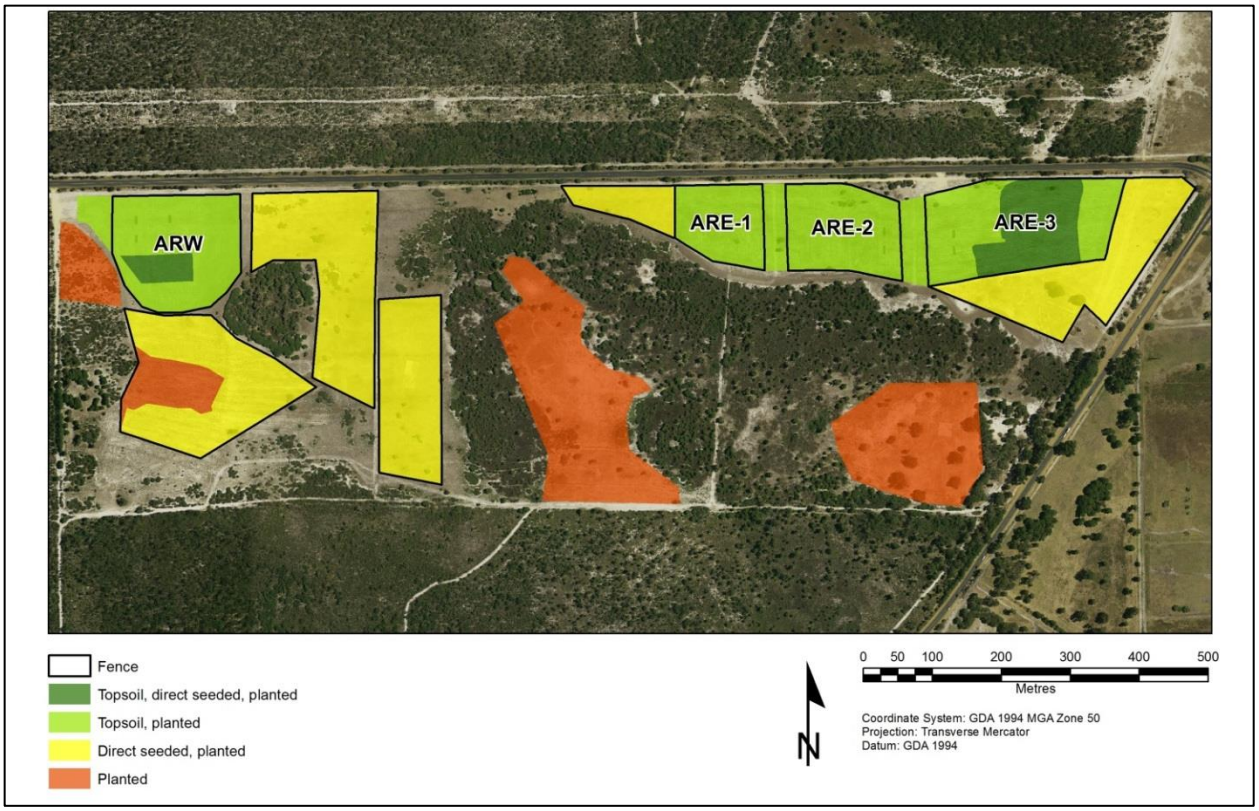

Figure 3. Anketell Road restoration site showing total areas fenced, direct seeded and planted from 2012 to 2016. Four separate management areas with respread topsoil are labelled.

4. Direct Seeding and Hand Seeding

Direct seeding was an efficient method for revegetating areas with few pre-existing native plants. In 2012-2016, a total of 15.5 ha at Anketell Road and Forrestdale Lake were direct seeded for the BWR project by Greening Australia WA to establish some key banksia woodland species. Seeds were mixed with wetting agent and fertiliser and applied using seed drill technology (see Fig. 4A). In general direct seeding was successful at restoring banksia woodland plants, but plant diversity and density was substantially lower in areas without respread topsoil, and several years of planting and seeding was required because of high summer attrition (Section 3).

In May 2016, 2.5 ha at Anketell Road were direct seeded by Greening Australia WA in areas that did not receive topsoil but had patchy results from previous planting and direct seeding (see Fig. 4B). Seedlings emerged well in these areas, but high mortality is expected over summer. Success rates for direct seedling will be measured in autumn 2017.

Other areas of the restoration sites contained bare patches that were inaccessible by vehicle without causing significant damage to the existing revegetation. Infill of these areas (around 10 ha at Anketell Road and 1 ha at Forrestdale Lake) was done by hand direct seeding in May-June 2016 with Parks and Wildlife staff and volunteers. This was done 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 (see Fig. 4C). The seeds were then covered over with a thin layer of soil. As with the machine direct seeding, seeds were mixed with wetting agent and fertiliser, as well as sand and vermiculite to bulk out the seed mix. This method resulted in good germination overall, but results were uneven, with some areas of very dense seedlings (see Fig. 4D) and other areas where seedlings were widely spaced. Over 30 kg of seed was used, including about 25 kg of the cycad *Macrozamia* which has very large seeds that were distributed by hand as they do not fit through the machinery.

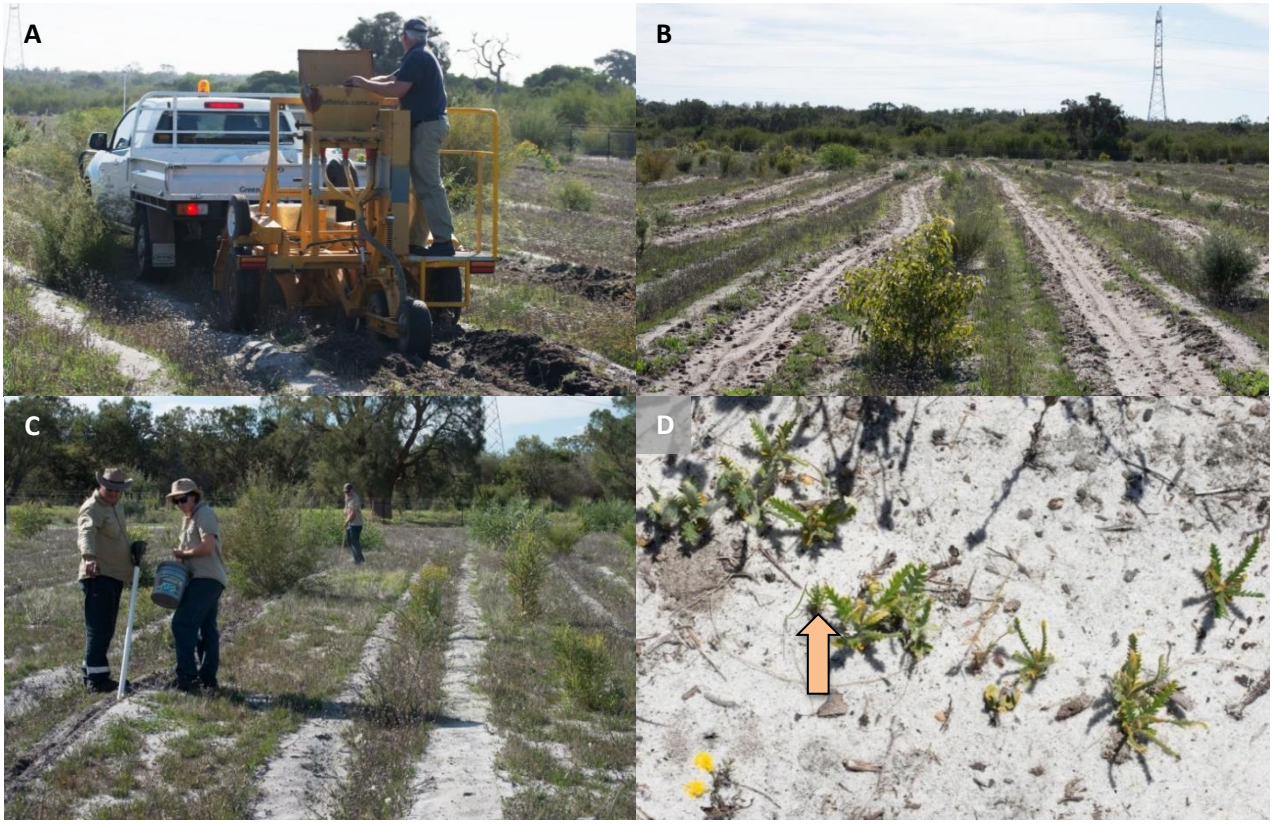

Figure 4. Direct seeding undertaken in 2016. **A.** Greening Australia WA using a seed drill at Anketell Road. **B.** The same area with the newly seeded rows (with planting and seeding from previous years between the rows). **C.** Hand direct seeding with the help of Parks and Wildlife Regional Parks staff in late May 2016. **D.** Seedlings resulting from the hand direct seeding. This image shows 15 banksias and one Christmas tree (*Nuytsia floribunda,* shown by the arrow) within <1m of one another.

Figure 5. Examples of photo-monitoring from the restoration sites showing annual increments in vegetation cover. **A.** This example shows an area at Anketell Road from April 2013 (one year after topsoil transfer and prior to any planting), to March 2016. **B.** This time sequence shows an area at Forrestdale Lake before topsoil transfer (February 2012), until March 2016. The impact of grazing on vegetation can be clearly seen outside the fenced area (left side of images).

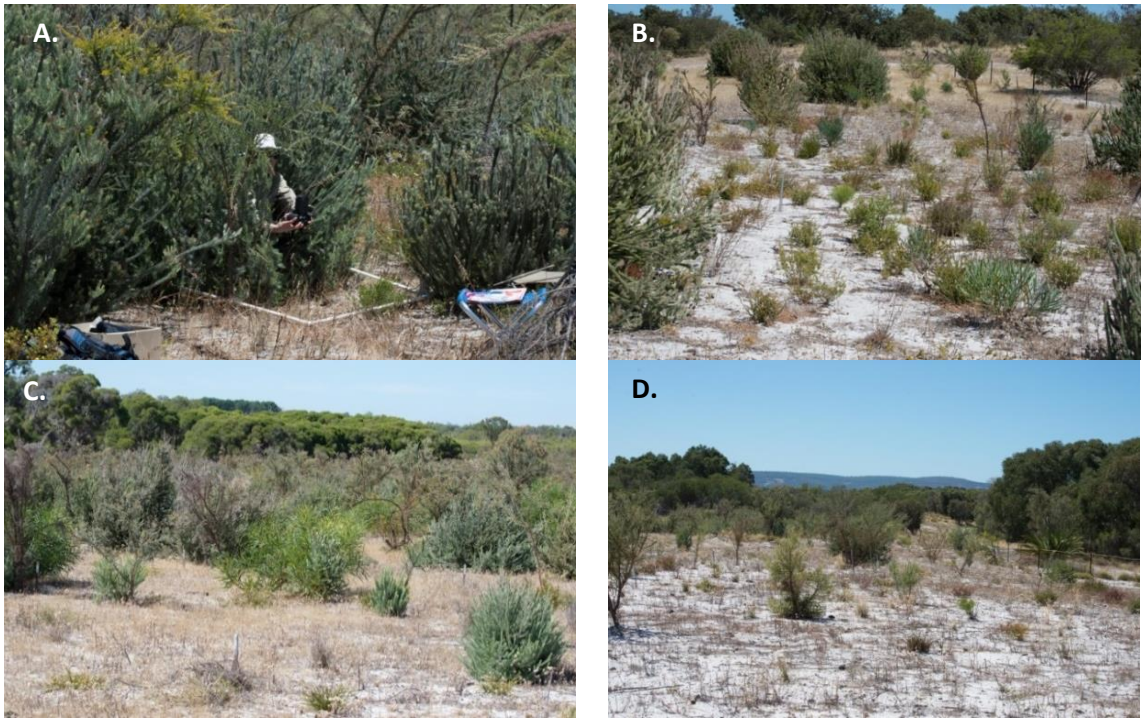

Figure 6. Restoration sites in 2016 **A.** Anketell Road taking monitoring photos in dense vegetation. **B.** Forrestdale Lake area with higher seedling survival. **C.** Anketell Road transition area with low survival in foreground and dense natives in background. **D.** Forrestdale Lake area with low seedling survival.

5. Monitoring Survival and Recruitment in Restoration Areas

Monitoring of restoration areas for comparison with the completion targets (shown in Table 5) required a combination of four different methods that were undertaken at different times. The cover and density of all species was measured within 1x1m plots arranged in rows, since it was impractical to quantify annual plants and seedlings on a larger scale. In 2014, the BWR project also set up a series of 80 larger 5x5m quadrats for counting planted and direct seeded plants. These quadrats are also being used to count all perennial natives and weeds. They are arranged in groups of four to create virtual 10x10m plots for comparison with reference sites. To establish species area relationships, plant diversity was measured in a series of nested plots ranging in size from 5x5m to 50x50m at Anketell Road. Twelve 25x25m plots are used to measure tree density, flowering and seed production. Photo-monitoring points have also been established in all restoration areas.

5.1 Rainfall and Climate

Plant survival and growth during the first four years of restoration at Anketell Road and Forrestdale Lake restoration sites was seriously impacted by periods of severe drought in autumn, winter and spring (Fig. 7). A rapid decline in rainfall in spring substantially increased the mortality of seedlings and planted tubestock at restoration sites in 2012, 2013 and 2015. There was near average rainfall in 2016.

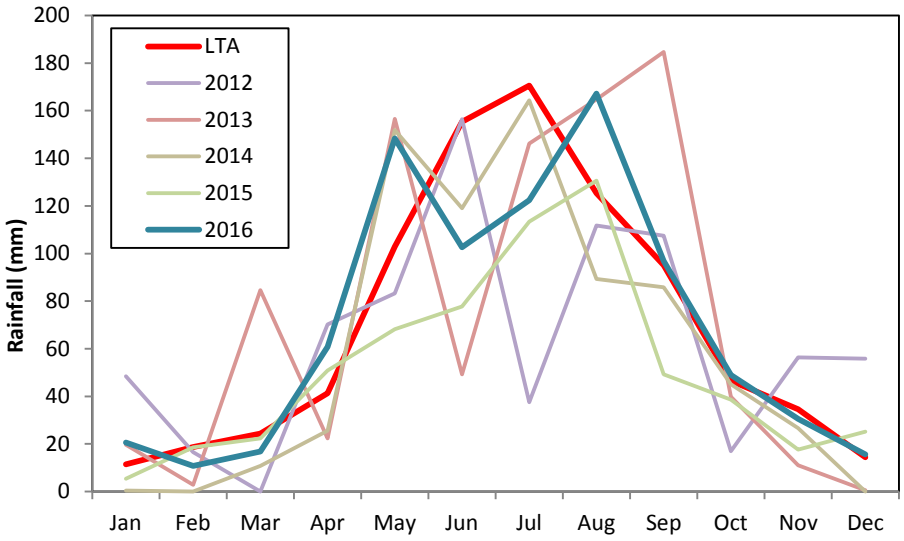

Figure 7. Rainfall (mm) at the Anketell Road weather station from 2012 to 2016 (www.bom.gov.au). 2016 had average rainfall. In other years, steep declines in rainfall in spring in combination with periods of autumn, winter and/or spring drought had a major impact on plant survival. The long-term average (LTA) is the mean from 1985 onwards.

5.2. Plant Cover

At four years after restoration began, vegetation on the sites is becoming more established (Fig. 5A, B), though still patchy, with areas that are denser (Figs. 6A, B) and areas that are more sparse (Figs. 6C, D). To measure the abundance and cover of all species, we monitored 113 1x1m plots across the sites each year to compare species present before the topsoil was spread with those present each year after restoration commenced. These plots are arranged along six transects at Anketell Road and nine at Forrestdale Lake and provided the following results, as shown in Figures 8 to 10:

- The average cover of perennial native species has increased gradually reaching an average of 15% at Anketell Road (Fig. 8) and 6% at Forrestdale Lake (Fig. 9) in the fifth year of restoration (2016).
- Perennial weeds have substantially declined as a result of weed control (Figs. 8, 9).
- Cover of annual weeds and annual native plants was initially much higher than perennial species but varies widely from year to year because of dependence on rainfall (Figs. 8, 9).
- Several perennial weed species were widespread across the site but had less than one per cent average foliage cover by spring 2016 (Fig. 10).

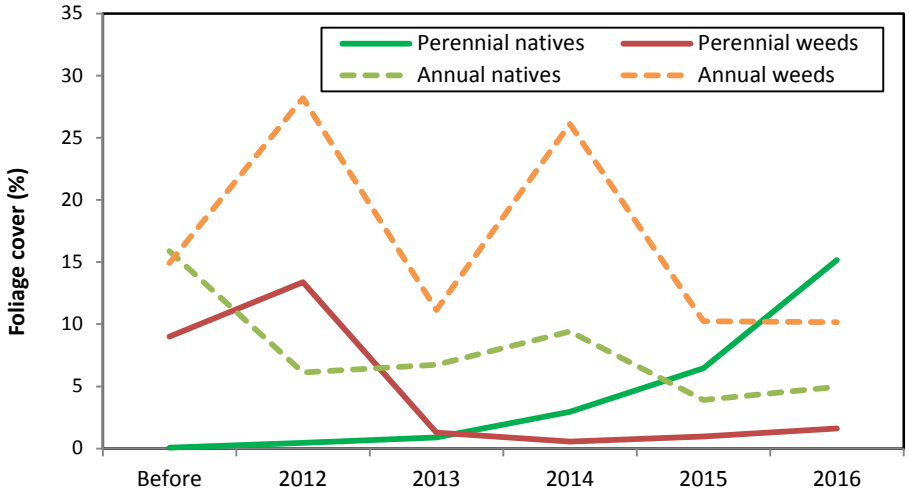

Figure 8. Changes in foliage cover of different plant categories at the Anketell Road restoration site. Results show cover in the 1x1m plots (fenced plots only) before restoration and for the five years after restoration activities commenced (topsoil transfer, planting and direct seeding).

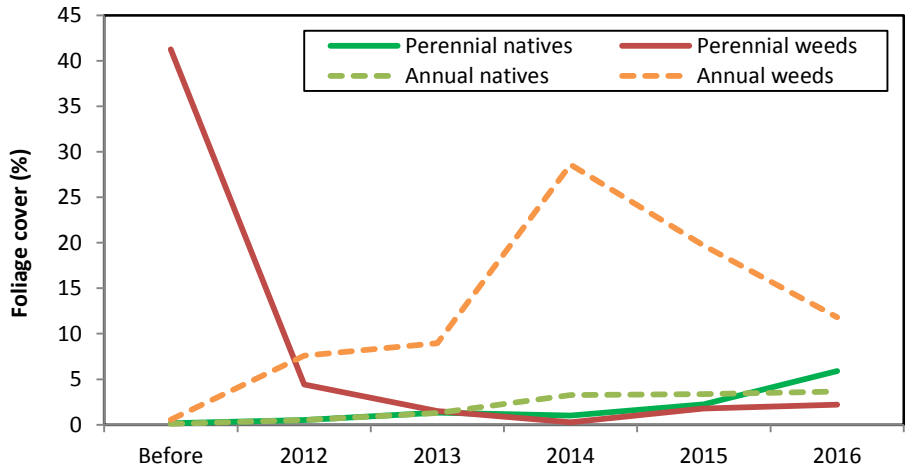

Figure 9. Changes in foliage cover of different plant categories at the Forrestdale Lake restoration site. See Figure 8 for details.

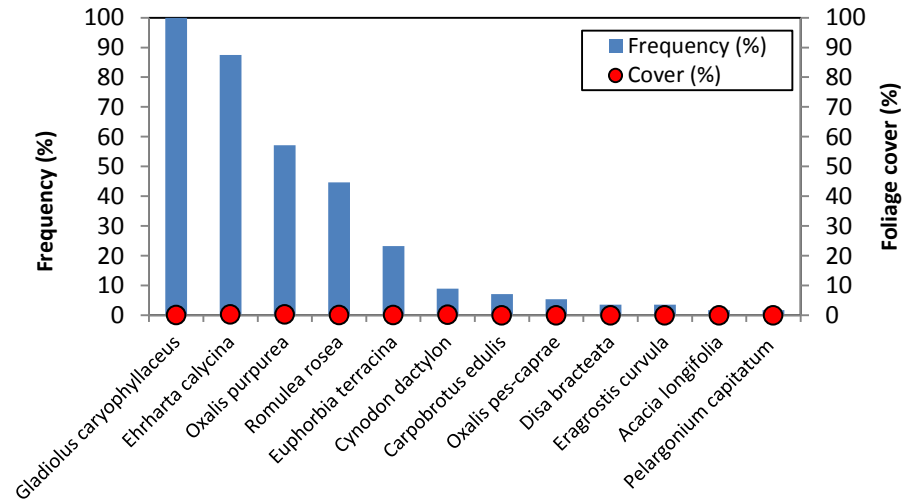

Figure 10. Frequency and foliage cover of perennial weeds at Anketell Road in spring 2016. Some were widespread at the site, but all had low average cover (<1%). Data are from 5x5m quadrats (n = 56). Red dots show total cover (scale on right).

5.3. Plant Density

Total native plant density, which is primarily from topsoil seed bank germination, peaked at over 700,000 stems per hectare in 2013. This initially included over 500,000 annual native plants, as well as about 170,000 small perennial native plants per hectare. However, many seedlings did not survive severe summer drought. The density of weeds was also initially very high, at one to two million stems per hectare, but is slowly reducing. Survival of nursery-grown seedlings planted on site was low due to three consecutive extremely hot and dry summers (Section 5.1), but a substantial number were still alive in 2016. By late 2016 there were

about 18,000 native perennials per hectare, many of which were derived from the topsoil seed bank (Fig. 11). This was sufficient to meet restoration targets in about 70% of areas with topsoil (Section 5.6).

Tree density (summarised in Fig. 12) shows that *Banksia attenuata* and *B. menziesii* are most common tree species, followed by *Eucalyptus todtiana* and *E. marginata*. *Banksia ilicifolia*, *Corymbia calophylla*, *Allocasuarina fraseriana*, *Nuytsia floribunda* and *Melaleuca preissii* trees are also present, but are less frequent. *Eucalyptus rudis* trees are now common in several of the direct seeded or infill planting areas. The density of trees reached target levels (Table 5) in most areas in 2016, but these include many new seedlings that are expected to suffer high summer mortality rates (Fig. 12). In general, the survival rates of eucalypt trees was higher than banksias from planting or direct seeding, but a much greater number of banksia trees were planted or sown initially, to match vegetation in reference sites.

Understory species dominate perennial native plant density (Fig. 11). Most of these species recruited from the respread topsoil. These include many shrubs and herbs as well as geophytes, which grew from seed, tubers or roots transferred in topsoil (Appendix 2). In 2016, plant density has reached completion criteria targets in most areas (Fig. 17). However, there were several sections of Anketell Road and Forrestdale Lake that are problematic for unknown reasons that may require additional planting or seeding in future years (see Section 5.6).

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 had little impact. A summary of this work is provided in Appendix 3.

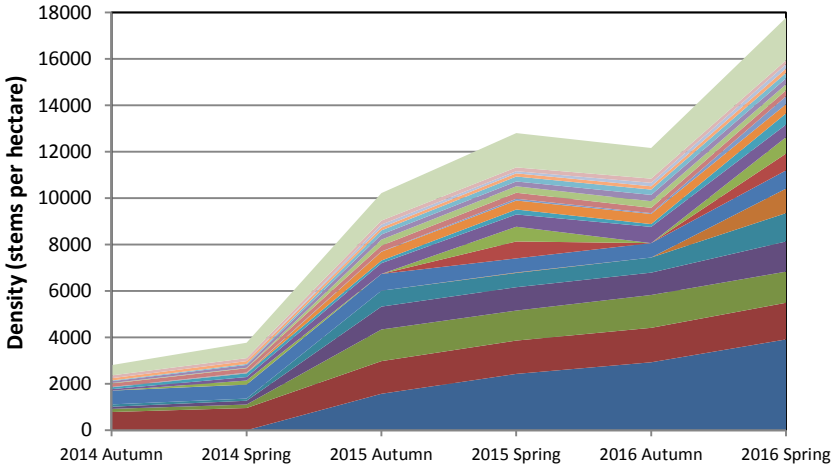

Figure 11. Increases in the average density of perennial native plants in 5x5m plots at the Anketell Road restoration site. The top 12 species in order of decreasing abundance (bottom to top) are *Laxmannia squarrosa, Gompholobium tomentosum, Scholtzia involucrata, Hibbertia subvaginata, Lechenaultia floribunda, Drosera paleacea, Jacksonia furcellata, Chamaescilla corymbosa, Burchardia congesta, Laxmannia ramosa, Banksia attenuata* and *Leucopogon conostephioides*. The uppermost category includes 58 less common species combined.

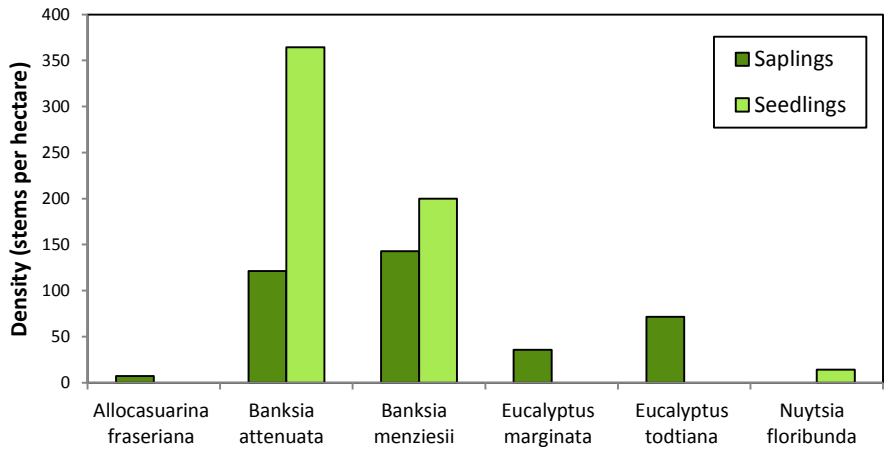

Figure 12. The density of trees in 5x5m monitoring plots at Anketell Road. The total density of all trees was 325 stems per hectare with a mean density of 250 stems per hectare for banksia trees. An additional 800 stems per ha of seedlings germinated in 2016 from hand seeding (see Section 3). Survival of these seedlings will be determined in 2017.

5.4. 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 160 native plants found at both sites (Appendix 2). The diversity of plants in 10x10m plot equivalents is approaching targets based on reference plots after five years (Table 5). The majority of native species found in Jandakot Airport reference plots have either germinated from topsoil or are included in the list of planted or seeded species for the restoration sites. However, some key differences were also noted, including 22 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. 13), but most are disturbance opportunists (i.e. plants that germinate from topsoil after disturbances such as fire). The most common plants derived from respread topsoil include annuals species of *Austrostipa, Podotheca* and *Trachymene* and small shrubs such as *Hibbertia subvaginata* and *Bossiaea eriocarpa*. 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* (e.g. Fig. 6A). These species 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 over 92 species of weeds present in the restoration areas, the majority of which are of limited concern because they are shade intolerant small annual weeds which are expected to diminish in importance with time as total foliage cover increases.

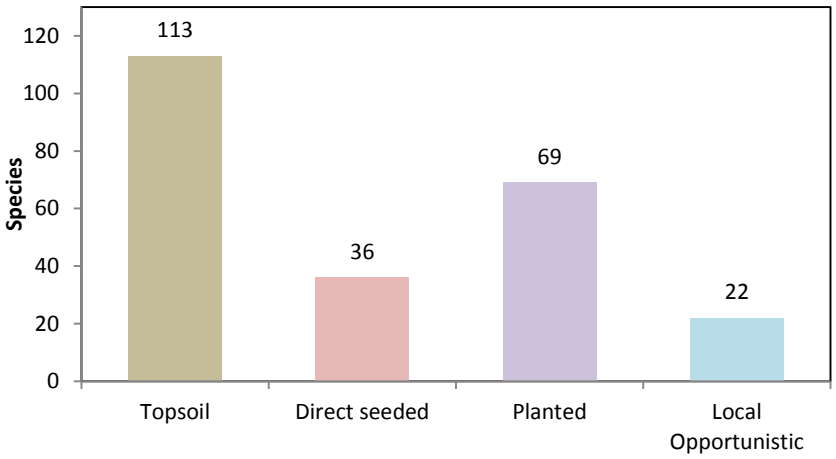

Figure 13. The number of native plant species recruited from different propagation sources. There is some overlap between categories, especially for planted and direct seeded species. There are a total of 159 species which are listed in Appendix 2.

5.5. Tree Survival and Growth

Tree growth is summarised in Figures 14 and 15 and in general eucalypt trees are growing faster than banksias, which grow about 0.4m in height each year. The oldest trees were seeded or planted in 2012, so are 4 years old and most are between 1-2.5m tall. However, some trees are much taller than this, with a few that are over 3 m tall, as shown in Figure 16. Figure 14 also illustrates how the number of trees has increased over time, primarily due to planting of tubestock.

The majority of individual trees have yet to flower, however some relatively small *Banksia menziesii* have been flowering and setting seed for 2 years. The first jarrah trees are now flowering and *Banksia attenuata* and *B. ilicifolia* both flowered for the first time in 2016 (a flowering jarrah and *Banksia attenuata* are illustrated on the front cover of this report). The first seed set and recruitment of seedlings from trees planted on site were found in 2016 (Fig. 20).

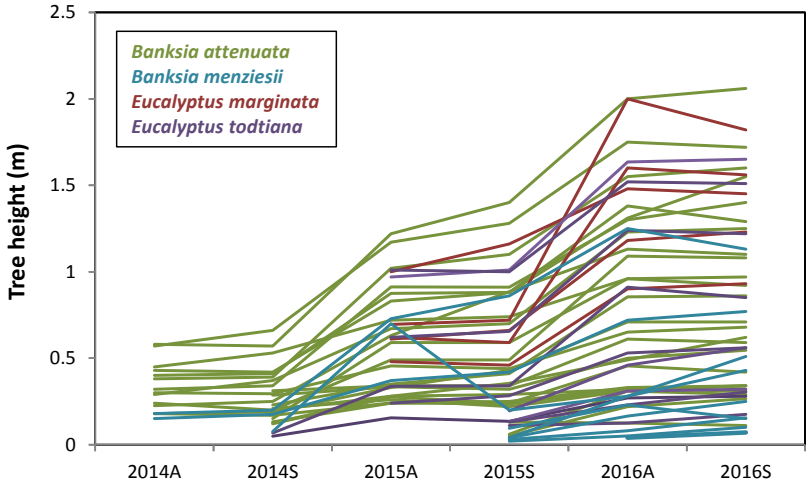

Figure 14. The height of all trees in 5x5m monitoring quadrats plotted separately over the first 4 years. This graph also shows how the number of trees increased due to planting in 2014 and 2015. There were two measurements each year in spring (S) and autumn (A). Eucalypt trees are less common than banksias in these plots and their size was not measured in 2014.

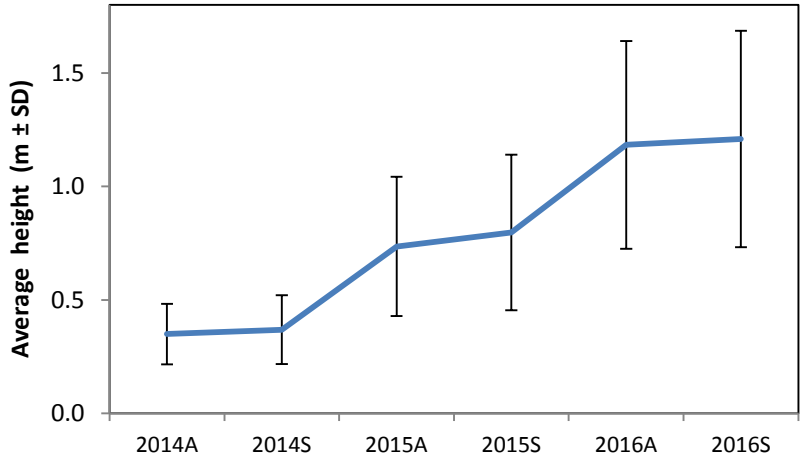

Figure 15. The average growth rate of candle banksia (*Banksia attenuata*) trees over the first 4 years. This graph shows trees planted in 2013 or 2012. Tree growth occurs primarily in summer. Error bars are standard deviations of the mean (n = 13).

Figure 16. Some of the tallest eucalypts from four-year-old direct seeding at Anketell Road. One jarrah tree, that stands over 3 m tall, has already flowered and set seed.

5.6. Spatial Variability in Restoration Sites

Figure 17 shows how plant density and cover varies spatially across the Anketell Road restoration site. Plant density has reached the target of 8000 stems per ha in most areas where topsoil was spread, but about 30% of plots remain below the target level (see Fig. 18). The upward trend in Figure 18 is due to targeted planting in areas with low plant density, as well as continued plant recruitment from topsoil. The situation at the Forrestdale lake restoration site is similar, but there remain areas with low plant densities (Fig. 18). Examples of areas with good and poor vegetation establishment at both sites are shown in Figure 6. Some of the areas with low plant cover at Forrestdale Lake are likely to have major problems with soil structure or chemistry due to the presence of buildings, tracks and gardens that were removed after the land was purchased for conservation.

Plant cover is generally lower in areas with direct seeding and planting only, but is starting to increase (total area 12 ha at Anketell Road). A more detailed monitoring program in areas restored from 2014 onwards will commence in 2017. In these areas a four year program of seeding and planting has resulted in a substantial increase in numbers of banksias, eucalypts and large shrubs. However, overall plant densities are much lower when compared to areas established with topsoil in 2012. Plant survival and growth also tends to be more variable within these areas. Areas without spread topsoil from Jandakot Airport have lower diversity and density targets for understory plants, but overstory targets are the same as in other areas.

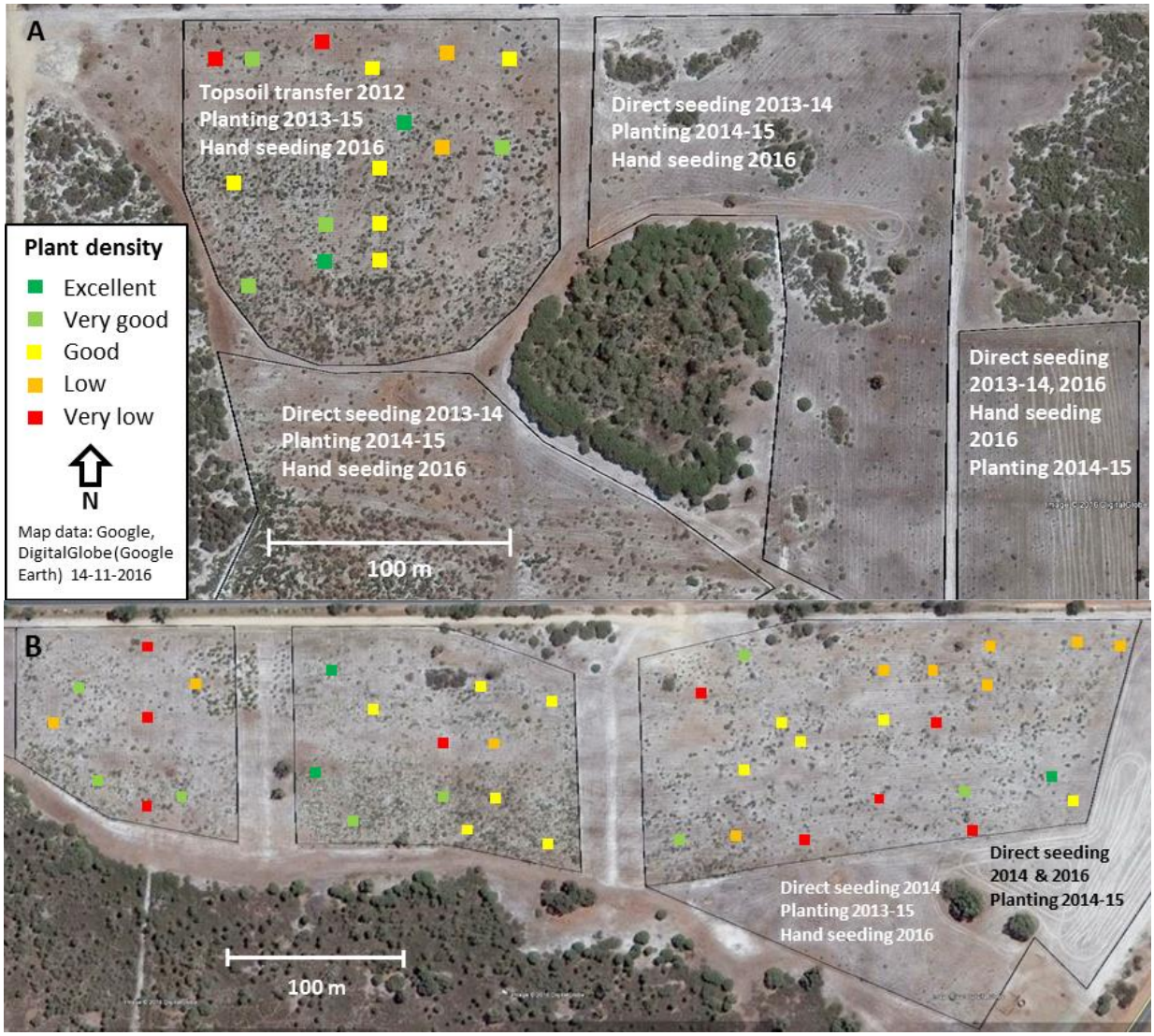

Figure 17. Restoration monitoring results plotted over an aerial photo from November 2016 to show variations in plant density and cover in restoration areas. These maps are of (**A**) western and (**B**) eastern areas at the Anketell Road site.

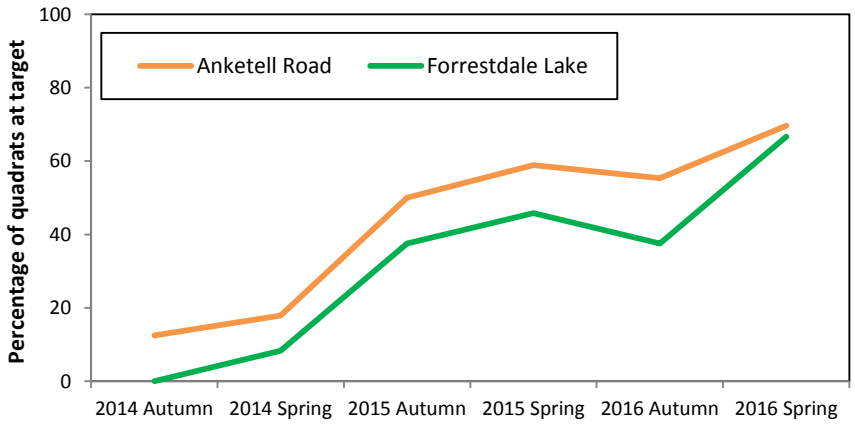

Figure 18. The proportion of monitoring plots reaching the target density of 7000 stems per ha. Data are from 5x5m monitoring plots.

5.7. Restoration Outcomes Relative to Targets

Restoration outcomes relative to completion targets are summarised in Table 5. After four years, most diversity targets have been reached, but seed germination from the topsoil was highly variable so there are some areas with more weeds than natives. As illustrated in Figure 13, the topsoil seed bank provides about half of the species present, but this does not include any of the trees and relatively few large shrubs which have canopy stored seed. Both planting and direct seeding have provided sufficient numbers of trees and large shrubs in most areas with topsoil before the current summer, but this will need to be reassessed in the autumn of 2017.

Additional planting and seeding occurred in 2016 in most areas without topsoil (17 ha) and some areas with topsoil. It is expected that differences between revegetated and reference sites will continue to decrease over time as native plant growth and cover increase and supress common shade intolerant annual weeds. Ecosystem functional targets were also assessed. In the first five years, 129 plant species flowered many of which were perennials (see Fig. 19, Appendix 2) and substantial pollinator activity and seed set were observed at both restoration sites.

One of the key objectives of this project is to evaluate the relative cost effectiveness of different methods for restoration of banksia woodland. Topsoil transfer was the most efficient method for restoring native plant diversity, but planting or seeding was also required to establish trees and some shrubs. It also needs to be noted that topsoil transfer has not been successful in some other restoration projects, since it requires topsoil source areas to be free of major weeds and diseases such as *Phytophthora* dieback. Topsoil source areas also need to have sufficient numbers of plants that accumulate seed in topsoil, which is not always the case.

Table 5. Restoration outcomes relative to targets set to assess vegetation in restoration sites (topsoil areas). Note all values were measured in spring 2016 and some will decrease due to drought in the 2016/2017 summer.

Criteria	Target	Status in late 2016
Total species richness	Maximise native species richness *There were **>80 species** present in in the topsoil source area at Jandakot Airport*	About **160** native species (highly variable spatially)
Average species richness per 10x10m quadrat	Return 60% of average number of native species recorded in reference quadrats (**19 species**). *There were 27-39 native species per reference quadrat (average 31).*	**24 to 47** species per quadrat (average 37)
Tree diversity	Presence of all trees at reference plots (*Adenanthos cygnorum, Banksia attenuata, B. ilicifolia, B. menziesii, Eucalyptus marginata, E. todtiana* and *Nuytsia floribunda)*	**All present** - planted and seeded. Many trees are >1 m tall
Tree density	Establish at least **300** stems per ha	**325** per ha (810 per ha incl. seedlings)
Carnaby's cockatoo food plants	This consists primarily of banksias - **250** stems per ha	Banksias only: **245** per ha (690 per ha incl. seedlings)
Average understory species richness per 10x10m quadrat	Return 60% of average number of native understory species in reference quadrats (**17 species**). *There were 25-36 native understory species per reference quadrat (average 29).*	**22 to 44** native species per plot (average 35) in topsoil areas (lower elsewhere)
Total density of native perennial plants 10x10m quadrat	Establish **7,000** stems per ha	**3,000 - 41,000** stems per ha (average 16,000)
Annual native plants	No target set and very much lower in reference sites	**>1,500,000** per ha
Key understory species	Separate targets set for top 10 most important species from reference plots	Most of these species are common but some are rare.
Weed cover	Manage serious weeds, especially perennials, monitor annual weeds and manage if necessary	Perennial weeds effectively managed, but annual weeds are common

5.6. Ecological Interactions

A. Flowering, Pollination, Seed Set and Succession

Over 80% of the native species flowered by year four (Fig. 19). Larger plants, especially trees, require longer to flower. Flowering of *Banksia menziesii* commenced in 2015 and flowering of *B. attenuata* and *Eucalyptus marginata* in 2016, but only a few individuals of these trees have flowered so far. Plants that flowered prolifically in 2016 included 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 (see Section 9).

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* and *Gompholobium tomentosum* which tend to be most common after fire in banksia woodlands. Both species flowered prolifically so may have produced sufficient seed to replenish the topsoil seed bank.

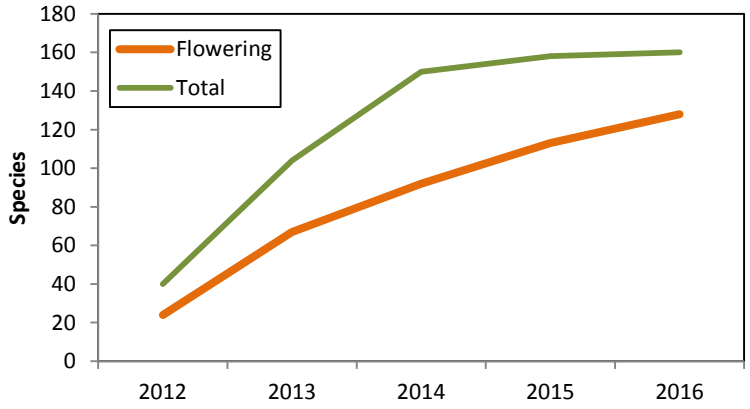

Figure 19. Increases in the number of plant species present and flowering at both restoration sites over the first five years after topsoil transfer. These totals also include species that were planted or direct seeded. Species are listed in Appendix 2.

Figure 20. The first self-sown banksia seedlings were found this year, but these are rare (left). Second generation seedlings of the overstory shrub *Jacksonia furcellata* are more common (right).

B. Grazing, Parasites, Fungi, etc.

Examples of harmful or beneficial ecological interactions that were observed at revegetation sites are listed in the 2015 BWR report and briefly summarised here:

1. We observed frequent grazing of banksia seedlings by invertebrates.
2. Broomrape (*Orobanche minor*) was a common parasitic plant in restored areas but primarily attacks weed species. This resulted in reduced vigour of capeweed in some areas.
3. Mycorrhizal and saprophytic fungi were observed to fruit in restored areas.
4. A smut fungus (*Tilletia ehrhartae*) that attacks veldt grass was observed.

6. Rehabilitation of Habitats by Weed Management and Fencing

Sites for weed control and other management actions funded by the BWR project are listed in Table 6. These areas were chosen after a strategic assessment of banksia woodland areas on the Swan Coastal Plain, site visits and weed mapping in 23 reserves, of which 16 were newly mapped for this project. Large areas were identified where fencing and gates were required to control illegal access and rubbish dumping and to reduce the spread of weeds and *Phytophthora* dieback by off-road vehicles. The BWR project has also funded major weed management, fencing and restoration works in 10 of the most important natural areas on the Swan Coastal Plain in projects managed by Parks and Wildlife's Swan Coastal District and the Urban Nature Program (Jackson et al. 2016).

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

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

Weed management focussed on perennial weeds which are highly competitive with native plants. In addition to 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 have been targeted (see Table 6). Each weed species has a specific biology which dictates timing and chemical applications required to achieve high mortality rates (florabase.dpaw.wa.gov.au, accessed 2013). We 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 20 bushland areas and two restoration sites had weed control works funded and managed by the BWR project (see Fig. 24 and Table 6). A summary of the 2016 works follows:

1. The two restoration sites, Anketell Road and Forrestdale Lake (35 ha), were sprayed to manage perennial veldt grass in 2016. Hand removal or spraying of lupins (*Lupinus* spp.), pigface (*Carpobrotus edulis*), watsonia, Geraldton carnation weed*,* arum lily and woody weeds such as *Acacia* spp. was carried out at these sites by Conservation Employees, Green Army and Work for the Dole teams.
2. A total of 85 ha were sprayed for veldt grass at Kogolup Lake, Shirley Balla Swamp and The Spectacles (Jandakot and Beeliar Regional Parks). The City of Cockburn sprayed a total of 8 ha for veldt grass in Rose Shanks Reserve in 2016.
3. Hand weeding by Green Army and Work for the Dole teams have continued to control major weeds including Sydney golden wattle (*Acacia longifolia*) at Shirley Balla and Harrisdale Swamps (2 – 3 ha). Larger plants have been cut down and saplings pulled out. Conservation Employees working for Regional Parks have helped control a new outbreak of Cape Arid kennedia (*Kennedia beckxiana*) at Shirley Balla Swamp.
4. The dolichos vine (*Dipogon lignosus*) outbreak at Harrisdale Swamp that was smothering trees was first managed in 2013 by cutting down vines and applying herbicide. Follow-up work by Conservation Employees and a Work for the Dole team continued in 2016.
5. New weed outbreaks have been discovered in Jandakot Regional Park in Shirley Balla Swamp, where a great deal of weed control has taken place, and at the Taylor Gibbs Rd Bushland. *Eucalyptus grandis* and some hybrid eucalypts have germinated in very large numbers in the reserves after fires through Banjup in February 2014 (Fig. 21). The new threat species are largely fast growing eastern states eucalypts that can attain heights of up to 50 m.

Weed management for perennial veldt grass commenced in 2013 (358 ha) and continued in 2014 (307 ha). In both 2014 and 2015, up to 52 ha were sprayed at Shirley Balla with funds allocated for weed control post-fire. In 2015, due to funding issues described in section 1.1, we were only able to respray the veldt grass monitoring quadrats (<1 ha). By spring 2015 veldt grass cover was again increasing in area covered, and flowering and seeding was observed. In 2016, spraying was limited to restoration sites and the areas veldt grass monitoring is taking place (120 ha).

We have observed that to be effective, at least three continuous years of spraying are required to manage perennial veldt grass because some tillers survive spraying and there are new germinants each year. We are currently planning further weed mapping and continued monitoring to direct further weed management. Due to funding delays that interrupted the weed spraying programme, it is likely that it will be necessary to respray some areas in 2017 and perhaps 2018 to ensure veldt does not regain its previous dominance.

As shown in Figure 22, spraying with grass-selective herbicide for veldt grass control was very effective in all quadrats that were sprayed two or more times in consecutive years. The exception was Shirley Balla where veldt grass recovery was substantial because part of the site (including the monitoring quadrats) was not sprayed in 2014 and 2015. Other weeds, mainly small annuals, responded to veldt grass management by increasing in cover at most sites, but their cover varied substantially from year to year due to seasonal differenes in rainfall (Fig. 22). In 2016, a nearby weather station recorded near-average rainfall (Fig. 7) whereas in 2012, 2013 and 2015 rainfall was below average. Annual weeds are of lesser concern as they do not seem to displace native species. Overall, in the short term, controlling veldt grass doesn't appear to cause a major increase in dominance of other weeds. A comprehensive study of the impacts of weed management on native plants will occur in 2017.

Figure 21. Major outbreaks of weedy eastern states eucalypt species occured in Jandakot Regional Park after the 2014 fire. These included a thicket of two and a half year old *Eucalyptus grandis* saplings (left). Mature *E. grandis* trees also occur in this reserve (right). We are in the process of testing different management approaches to control these woody weeds.

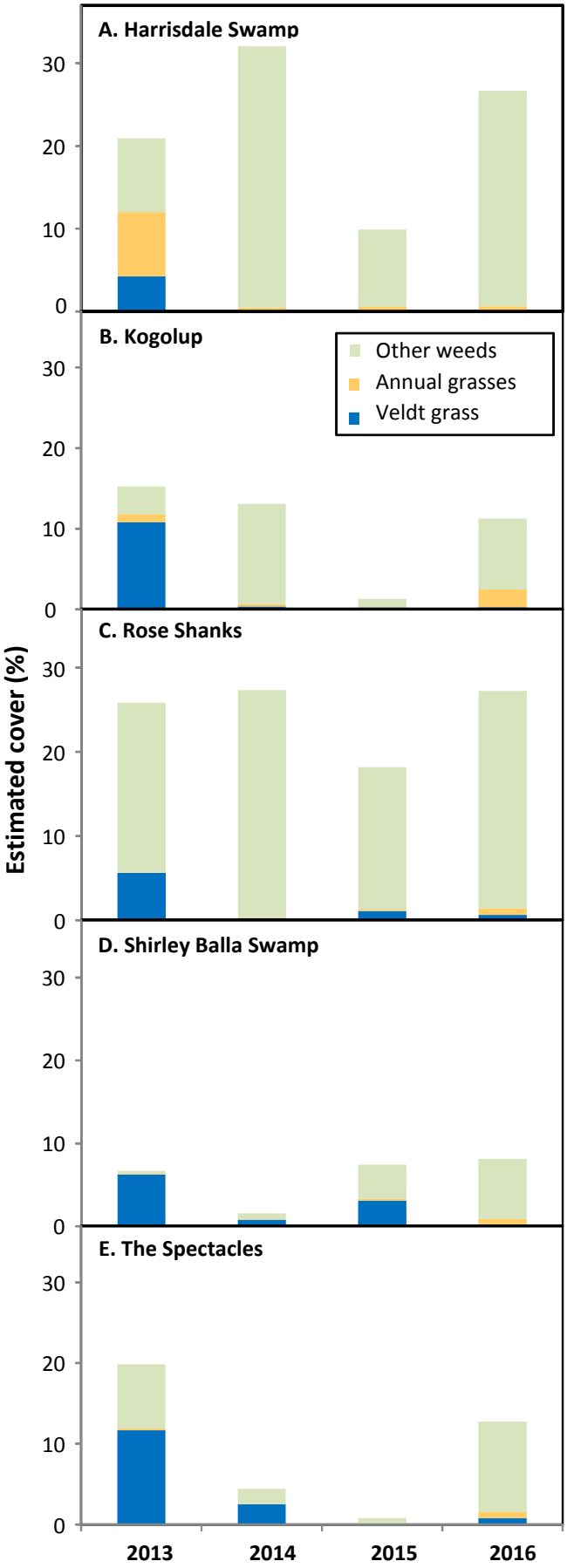

Figure 22. Weed cover before (2013) and after three years of weed management (2014-2016). These are averages from 3 sprayed quadrats at each site.

Figure 23. Time series showing weed management to remove veldt grass (2012-13) and recovery after fire (2014-16) in one quadrat at Shirley Balla Swamp.

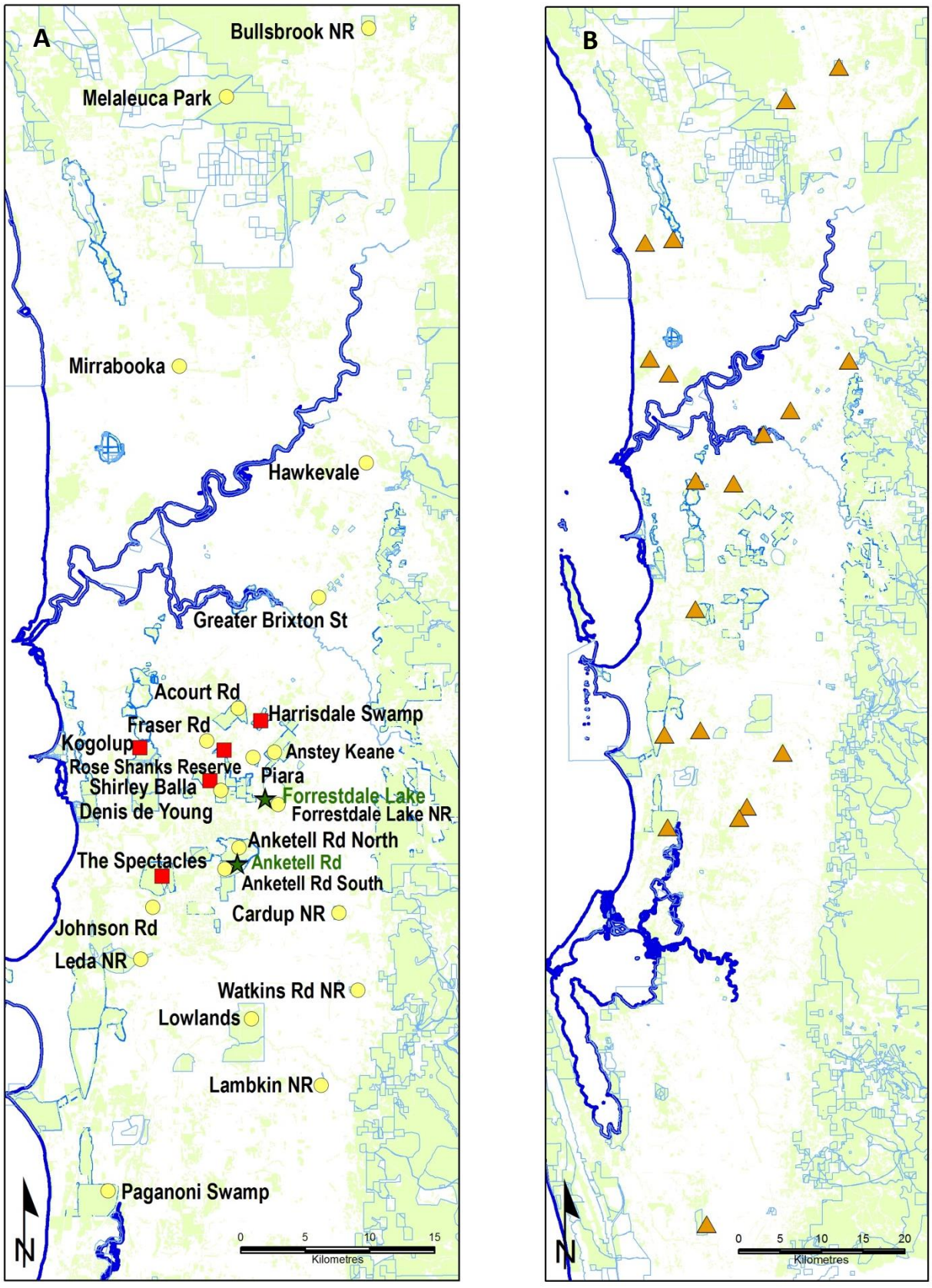

Figure 24. A. Areas where weed management funded by the BWR project occurred between 2012 and 2016 (yellow circles). Perennial veldt grass control sites with monitoring quadrats are shown as red squares. Restoration sites are shown as green stars. **B.** Locations of projects funded by Perth Banksia Woodland Community Restoration Grants (see Table 7).

Table 6. List of sites for weed control, fencing and other actions managed and funded by this project in 25 sites with intact vegetation and two restoration sites (pink).

Site Name (Project Management for weeds and fencing*)	Rank	Bush Forever Site No.	Weed mapped area (ha)	Weed management area (ha)	Fencing (km)	Weed management and other management
Anketell Rd North, Jandakot Regional Park (BWRP)	1	347	204	50		Veldt grass, freesia, arum lily, woody weeds
Anketell Rd Restoration Site, Jandakot Regional Park (BWRP)	1	Adj. 347 & 348	18	20	2.5	Veldt grass, pigface, couch, etc. Hand weeding - pigface, euphorbia, bulbs, etc.
Wandi Nature Reserve, Jandakot Regional Park (UN, BWRP)	1	347	UN	20		Veldt grass, freesia, pigface to protect DRF
Melaleuca Park (SCD)	3	399	53	10	1	*Euphorbia terracina*, woody weeds, fencing along Neaves Rd
Forrestdale Lake (Friends of Forrestdale, BWRP, 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 (Private Property, UN, SCD)	5	368	UN	50		Arum lily, castor oil and cotton bush.
Greater Brixton St Wetlands (UN, SCD)	7	387	UN	10	0.15	Ongoing eradication of bulbs, bamboo, couch grass in TEC, fences and gates
Denis de Young Reserve, Jandakot Regional Park (City of Cockburn)	9	344	CoC	20		Veldt grass, *Euphorbia terracina* (jointly funded by City of Cockburn)
Anketell Rd South, Jandakot Regional Park (BWRP)	12	348	51	12 (24)		Veldt grass, hand weeding of *Euphorbia terracina*, pigface, gladiolus
Anstey/Keane Dampland, Jandakot Regional Park (UN, BWRP)	15	342	UN	50		Veldt grass, *Euphorbia terracina*, cape tulip, black flag, Victorian tea-tree
Acourt Rd Regional Park, Jandakot Regional Park (BWRP)	19	389	67	20		Veldt grass, freesia, pampas grass, fencing
Kogolup Lake, Beeliar Regional Park (BWRP)	21	391	60	56		Veldt grass, pigface, *Euphorbia terracina*, freesia, watsonia, arum lily
Shirley Balla Swamp, Jandakot Regional Park (RP, BWRP)	22	263	131	60		Veldt grass control, euphorbia, bulbous weeds, arum lily, Sydney golden wattle, tree tobacco and Cape Arid kennedia
Cardup Nature Reserve (SCD, BWRP)	23	352	75	10	0.5	Woody weeds in TEC, veldt & love grass control and fencing
Watkins Rd Nature Reserve (SCD)	25	360	SCD	50		Various weeds followed by revegetation
Paganoni Nature Reserve, 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 Rare Flora habitat
Rose Shanks Reserve (in Fraser Rd Bushland) (City of Cockburn)	37	390	CoC	30		Veldt grass, *Euphorbia terracina*
Leda Nature Reserve (SCD, BWRP)	42	349	80	28 (75)	1	Veldt grass in prescribed burn area, fencing
Harrisdale Swamp, Jandakot Regional Park (BWRP, RP, Friends of Forrestdale)	43	253	53	40		Veldt grass, *Dipogon* sp. (climber), *Euphorbia terracina*, pampas grass, Sydney golden wattle
Hawkevale Bushland (SCD, BWRP)	47	122	10	10	0.97	Veldt grass control, woody weeds, fencing and rubbish removal
Piara Nature Reserve, Jandakot Regional Park (BWRP)	63	262	36	15		Veldt grass, *Euphorbia terracina*, arum lily, pampas grass and woody weed control
Johnson Rd, Kwinana (SCD)	69	272	10	2		Cape tulip, etc. to protect DRF and other assets
The Spectacles, Beeliar Regional Park (BWRP)	79	269	50	50		Veldt grass, arum lily, *Euphorbia terracina*, bulbous and woody weeds
Lambkin Rd Bushland (SCD)	95	375	SCD	2		African love grass, watsonia, etc.
Total			**924**	**640**	**12**	

*Land managers: BWRP = this project, RP = Regional Parks, UN = Urban Nature Program, SCD = Swan Coastal District, CoC = City of Cockburn. Areas in brackets are target areas when different from area sprayed in 2014.

7. Monitoring the Outcomes of Weed Management

A banksia woodland monitoring program was established in 2013. This program has 31 permanent 10x10m quadrats in five reserves where weed management is underway (Fig. 24A). 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. These quadrats are used to monitor plant understory and canopy diversity, density and cover. Photographs of one of these quadrats, both before and after weed spraying (and before and after fire) (Fig. 23), shows an increase in the visibility of native plants after veldt grass is eliminated. The overall dominance of perennial weeds was substantially decreased after spraying removed most perennial veldt grass (Figs. 22-23) and further weed management activities removed other perennial weeds (e.g. freesia and Sydney golden wattle). A major survey is planned for 2017 and the results of this survey will show the longer term impacts of veldt grass control on native and weed diversity, density and cover. Preliminary results of this study are presented in the 2015 BWR report.

The BWR project has published data on floristic diversity, density and cover data from 51 quadrats established in primarily upland banksia woodland south of Perth. These data are available at the Department's NatureMap website (naturemap.dpaw.wa.gov.au) and will be updated with subsequent years' surveys and with monitoring data from the BWR Project's restoration sites at Anketell Road and Forrestdale Lake. NatureMap is designed to provide land managers, researchers, community groups and the general public with comprehensive and up to date information on plants, animals, fungi and other groups of biodiversity.

8. Monitoring the Recovery of Banksia Woodland after Fire

A comprehensive summary of results from the BWR fire study was presented in the 2015 BWR annual report, with updated information presented here. A severe bushfire in Banjup in February 2014 burnt all seven BWR monitoring quadrats in Shirley Balla Swamp Reserve within Jandakot Regional Park (Fig. 24A), 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 quadrats have since been used to monitor changes in plant diversity, density and cover after fire. This monitoring occurred monthly for the first six months, then quarterly until November 2015, and then biannually until November 2016, 21 months after the fire. The results are summarised briefly here:

1. Plant cover was measured by visual estimation and photographic methodologies and is steadily increasing, reaching 80% of the pre-fire cover by 19 months post fire (Figs. 25, 26, 27).
2. Native plant cover was much greater than weed cover for the first 19 months after the fire (Fig. 27). Cover of *Austrostipa compressa*, a native fire-opportunist annual grass, was only high during the first year post fire but seeds should remain in the soil seed bank until the next disturbance event. Weed grasses, especially perennial veldt grass, gradually increased after the fire mainly in the unsprayed quadrats (Fig. 27). Cover of other weeds, predominantly annuals, peaked over winter.
3. Resprouting plants dominated initially, but those that recruited from seed became almost as diverse during the first winter after the fire. Species that recover by resprouting from the base, stem, rhizome, tuber and roots were all represented after the fire.
4. 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. However, veldt grass cover rapidly increased again due to lack of spraying in 2014 and 2015. It is once again being managed successfully by spraying in 2016 (Fig. 22D).
5. 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. 28). Banksia germination, which occurred from seed shed from cones in the canopy, was rare in 2015 and absent in 2016. About 70% of banksia seedlings that germinated in 2014 survived the

summer of 2014/15 (these are called yearlings in Fig. 28). There also were many *Nuytsia floribunda* seedlings in one area in 2015 (data not shown).

6. Aerial photographs spanning the period 1953-2016 show major changes in tree density and cover over time at Shirley Balla Swamp Reserve. Despite the lower resolution and quality of some of the older imagery, clear trends were apparent over this 60 year period, with tree density and cover peaking just before the 2014 fire (Fig. 29). Dead trees that may have been ring-barked, as well as areas that had been cleared by "scrub-rolling", were visible in the aerial photographs from the first three decades and relate to historical grazing activities in the area.

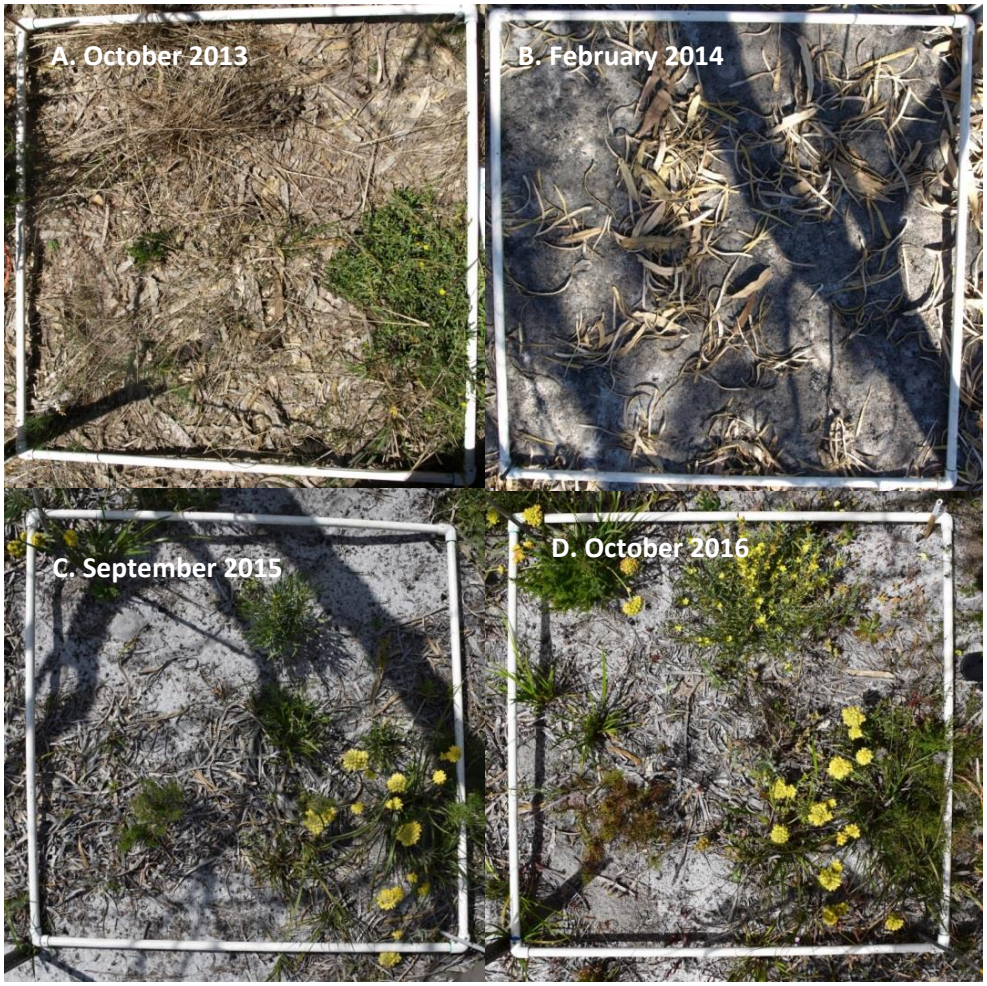

Figure 25. Time series showing the same 1x1m subplot at Shirley Balla over four years, both before (A) and after (B-D) the fire of February 2014. Photos have been used to calculate understory cover by a computer algorithm (Fig. 26) and by human estimation (Fig. 27).

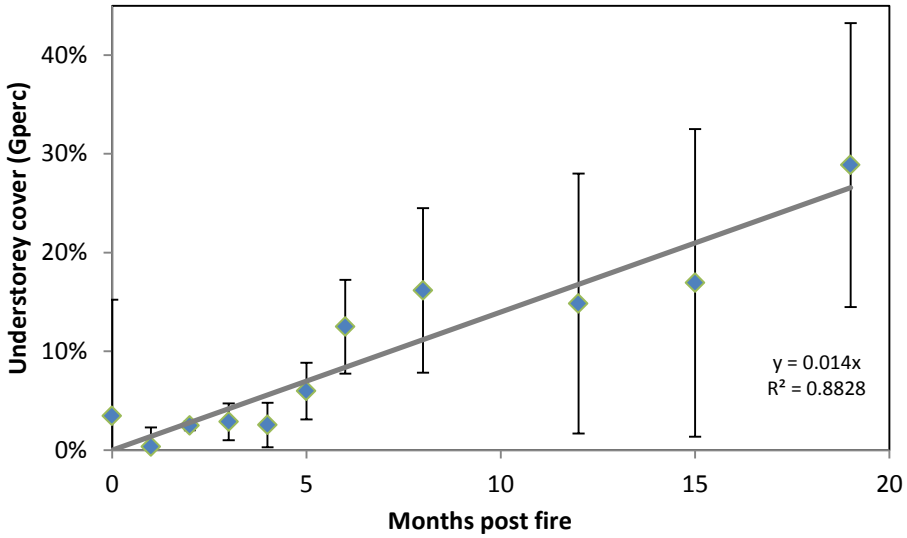

Figure 26. The recovery of understory plant cover calculated from downward facing photos using a computer algorithm. Increasing plant cover is shown for 19 months following the fire. Cover is averaged across 63 1x1m subplots in 7 quadrats. Error bars show standard deviation. Gperc is the computer algorithm use to calculate cover values.

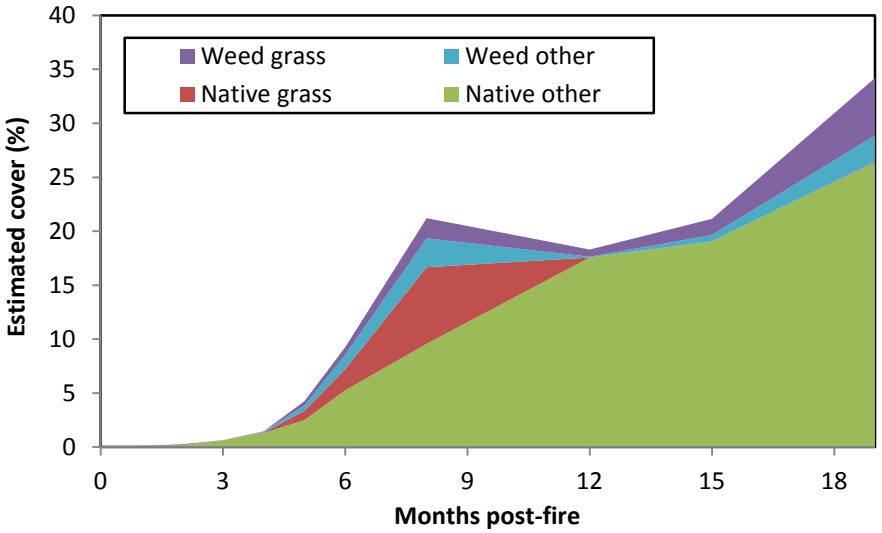

Figure 27. Total understory cover derived from visual estimation of photos of sixty-three 1x1m subplots over 19 months following the fire. Stacked areas show the relative cover of major plant groups. Note the peak of growth by native grasses (*Austrostipa*) in the first year (red).

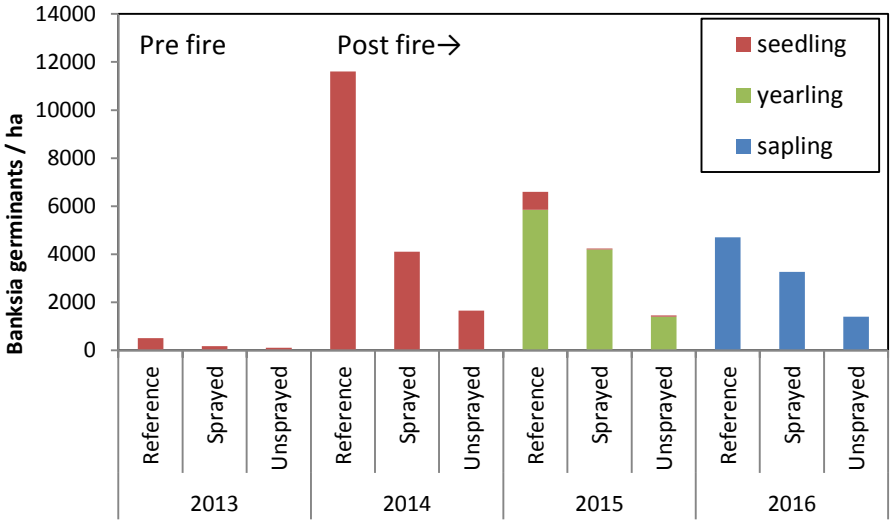

Figure 28. Banksia seedling germination at Shirley Balla Swamp before and during the first three years following the fire. The survival of banksia yearlings (one-year-old seedlings from 2014) and two-year-old saplings are also shown. Seedlings are primarily *Banksia attenuata* and *B. menziesii*. These are average counts from seven 10x10m quadrats.

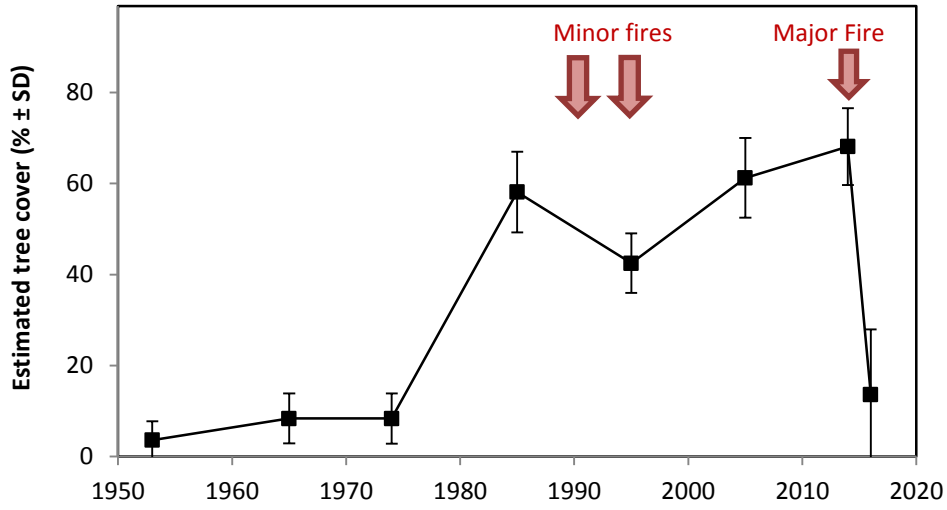

Figure 29. Tree cover changes over 70 years estimated from aerial photographs for eight 1 ha areas at Shirley Balla Swamp. Tree cover increased over time for seven decades following grazing and tree loss. There then were tree cover reductions due to a minor fire in 1996 and the severe fire in 2014.

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. 30). 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. 30D).

The BWR project also helped support the translocations of Wallabies from Jandakot Airport to Harry Waring reserve. Bruch 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 Parks and Wildlife, 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 Parks and Wildlife are committed to ongoing monitoring of this population.

Figure 30. A. Pollinators, such as nectar scarabs (*Neophyllotocus* sp. on *Melaleuca thymoides*). **B**. green spring beetles (*Diphucephala edwardsii* on *Acacia pulchella*) were abundant in spring 2016. **C** Beefly visiting *Lechenaultia floribunda*. **D.** Mating pair of western bearded dragons (*Pogona minor*) in the restoration site.

10. The Banksia Woodland Community Restoration Grants

October 2016 saw the completion of on-ground works by community groups funded under the Perth Banksia Woodland Community Restoration Grants using funding from the Jandakot Airport offset. Parks and Wildlife administered the grants to support community groups to manage and conserve banksia woodland. Twenty projects were successful from a pool of 35 applicants resulting in 16 groups working at 21 locations (Fig. 24B). Individual grants ranged from $5000 to $20,000 with a total value of $297,446 (ex GST) for banksia woodland restoration and management over the period June 2014 to October 2016. Six projects restored banksia woodland habitats through revegetation, four managed weed degradation, five managed areas for *Phytophthora* dieback infestations and five projects addressed a combination of revegetation, weed control and dieback management (Table 7).

Funding was allocated in two instalments, with the second instalment allocated in October 2015. Four projects had been completed during the first period with 16 projects continuing in 2016. The grant program and interim reporting process allowed for recipients to take an adaptive management approach and 12 projects applied for variations to extend or decrease the area of revegetation, increase infill planting, expand follow-up weed control, purchase extra equipment or materials or change the timing of activities. Reasons for variations ranged from a decreased capacity, lack of available seed, area affected by bushfire, actual expenses less than original budget or extra in-kind contributions by partner organisations.

In February 2016 a workshop was held for grant recipients to share some of the successes and challenges of working in banksia woodland, discuss project outcomes and early monitoring results. Each group that attended gave a short five minute presentation and the BWR also presented an overview of Parks and Wildlife's management and research outcomes for the 36 participants. Feedback showed that it was informative and a worthwhile opportunity to network with other groups.

Final acquittal reports were required in early 2017. Eighteen grants have been fully acquitted with final reports pending for two projects. Records of group contributions of cash and in-kind support and hectares restored have been included in Table 7.

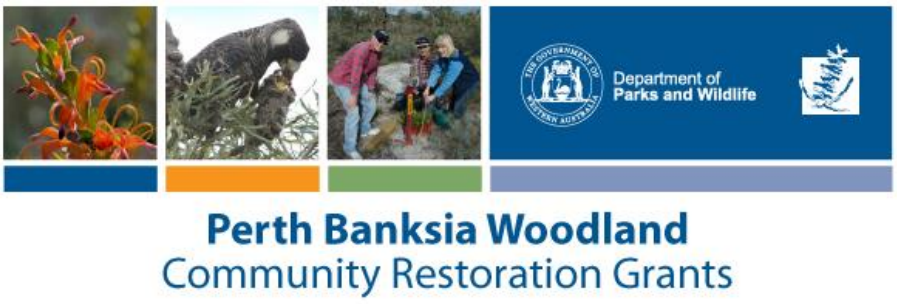

Figure 31. Logo for the community grants programme.

Table 7. Recipients of Banksia Woodland Community Restoration Grants (contributions still to be updated).

Main Organisation (Partners)	Project Title and Objective	Funding (ex GST)	Group and Partner Contribution	Area Restored (ha)
Baldivis Children's Forest (City of Rockingham, Kolbe Bush Cadets, CVA, community groups, Ardross PS)	Baldivis Banksia Woodland Wonderland with Baldivis Children's Forest (planting, fencing, etc.)	$12,750	>200 hours and plants (final report pending)	3
Birdlife Western Australia (BGPA, Friends of Bold Park)	Revegetating the Eastern Gateway for Carnaby's (planting, monitoring, etc.)	$20,000	Hours[1] and $5000	0.9
Ellen Brockman Integrated Catchment Group	Managing *Phytophthora cinnamomi* in Bullsbrook Nature Reserve	$18,970	Hours[1]	121
Friends of Hepburn and Pinnaroo Bushland, Inc. (City of Joondalup)	Control of Bulbous Weeds in the Hepburn Heights Conservation Area	$18,540	334 hours and $69,329	22
Friends of Ken Hurst Park (City of Melville, Green Army, SMRC)	Restoration of degraded areas in Ken Hurst Park	$12,275	476 hours, 475 plants and $300	0.3
Friends of Maida Vale Reserve (City of Kalamunda, EMRC)	The Friends of Maida Vale: Banksia Woodland TEC Restoration Project	$12,800	300 hours and $25,325	14
Friends of Queens Park Bushland (City of Canning)	Maniana Reserve Revegetation Project	$9,981	589 hours and $3,550	0.2
The Friends of Shenton Bushland, Inc. (City of Nedlands)	Restoring "The Barrens" as Cockatoo Habitat	$20,000	84 hours and $83,235	1.2
The Friends of the Spectacles (Kwinana Community Share)	The Friends of the Spectacles - Banksia Woodland Revegetation Areas	$20,000	870 hours, $28.30 and 350 plants	2.2
Greening Australia (Landowner, Alcoa, community group)	Peel Biolinks - Connecting Landscapes for the Future	$20,000	600 hours (estimated)	8.5
The Kingsley Montessori School	Montessori Weed Control	$5,060	269 hours	1
Landcare Serpentine Jarrahdale, Inc. (Landowner)	Thompson's Dieback Treatment Project	$8,655	18 hours; $1863.36	45
Landcare Serpentine Jarrahdale, Inc. (Landowner, Dieback Treatment Services)	Elliot Banksia Woodland Dieback Treatment	$20,000	40 hours; $5817.98	95
Landcare Serpentine Jarrahdale, Inc. (Landowner, Healthy Wetland Habitats – Parks and Wildlife)	Banksia Ridge : Removal of Eucalyptus camaldulensis at Rapids Road	$13,100	240 hours and $4687	12.8
Landcare Serpentine Jarrahdale, Inc. (Landowner)	Banksia Ridge Dieback Treatment and Mapping at Rapids Road	$6,000	50 hours and $2,000	n/a
Murdoch Environmental Restoration Group (Murdoch University)	Ecological Integrity and Black Cockatoo Habitat in Banksia Woodland Reserve Murdoch University	$20,000	300 hours	8
North Swan Land Conservation District Committee (WAPC)	Weed Control and Dieback *Phytophthora* management of Banksia Woodland in West Bullsbrook	$14,955	40 hours, $1881	40
South East Regional Centre for Urban Landcare, Inc. and Friends of Paganoni Swamp	Foliar spraying to control *Phytophthora cinnamomi* on the eastern boundary of Paganoni Swamp Reserve	$19,360	15 hours	677
Waterbird Conservation Group, Inc.	Rehabilitation of Cockatoo Habitat Canning River Regional Park	$5,000	Hours, $6600	4
Waterbird Conservation Group, Inc.	Banksia Woodland Restoration on a sandy rise adjacent to Maramanup Pool, Baldivis	$20,000	1279 hours and $8144	1.2
Total		$297,446	>5714 hours & $213,987.30	1,057ha

Notes: [1.] Hours for restoration workdays yet to be reported

11. Conservation of the Grand Spider Orchid (*Caladenia huegelii*)

One of the main focuses of the BWR project is to help conserve the grand spider orchid (*Caladenia huegelii*), a rare orchid that occurs in banksia woodland. Two of the largest populations of this orchid are at sites where management is supported by the BWR project. Rare flora surveys by BWR staff occurred at two sites in 2016, with more planned in 2017. The BWR project coordinates volunteers for surveys and a translocation of orchids in Banjup in 2016. The BWR project has also provided support for translocation of *Caladenia huegelii* into Jandakot Regional Park using offset funding from a development at Wandi (Fig. 32). This funding was used for seed baiting trials to identify translocation sites, as well as fencing and weed control in these areas. The BWR project has also supported the Friends of Ken Hurst Park for restoration work in habitats for *Caladenia huegelii*.

Figure 32A. Grand spider orchid (*Caladenia huegelii*.

B. One of four plants translocated from a development site in Banjup in 2016.

C. Seed bag protecting a pollinated flower at Banjup.

D. Workers fencing enclosures for translocation of plants rescued from a development site in Wandi (SERCUL Work for the Dole Team).

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 5.3 with an abstract provided in Appendix 3. A BWR-funded project by Dr Elaine Davison at Curtin University investigated dieback resistance in banksia trees by measuring sapwood invasion following inoculation with the pathogen (*Phytophthora cinnamomi)* 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

For most of 2016 the Project Management Group which oversees this project consisted of the Parks and Wildlife'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 was formed in 2011 to provide advice on scientific and management aspects of restoration programs such as the BWR project. Membership of this committee is listed in Table 8 and meetings were held every six to 12 months from 2011 to 2014. This committee did not meet in 2016, but a workshop is planned in 2017. Advice from this committee primarily concerns:

1. Management of the restoration programs.
2. Habitat restoration research priorities for conservation of biodiversity.
3. Development of criteria for flora and fauna that can be used to assess restoration outcomes.
4. Establishing links with other projects and sharing relevant data.
5. Collection and use of baseline and reference site data for monitoring.
6. Timeliness and progress of the programs and projects.
7. Feedback on reports and major documents produced by the programs and projects.

The principal stakeholders for this project are the Commonwealth Department of the Environment and Jandakot Airport Holdings. In addition to the Banksia Woodland Community Restoration Grants scheme, the BWR project has 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 9.

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

Table 8. Members of the Scientific Advisory Committee.

Prof. Richard Hobbs	Australian Laureate Fellow, School of Plant Biology, University of Western Australia
Prof. Neal Enright	Professor of Plant Ecology, Murdoch University
Dr. Ben Miller	Senior Research Scientist, Kings Park and Botanic Garden
Dr. Joe Fontaine	Lecturer, Restoration Ecology, Murdoch University
Prof. Will Stock	Prof. Environmental Management, Edith Cowan University
Dr. Mike Bamford	Consulting Ecologist, fauna expert
Dr. Katinka Ruthrof	Restoration Ecologist, Murdoch University
Stefan de Haan	Regional Manager, Swan Region
Steve Raper	Acting Regional Leader Nature Conservation, Swan Region
Dr. Geoff Barrett	Regional Ecologist, Swan Region

Table 9. BWR Project objectives and outcomes to December 2016.

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 diversity 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. PhD project at Murdoch University; 2. BWR banksia seedling and planting survival trials
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 underway
11. Nursery seedlings and cuttings	Produce sufficient tubestock of banksia woodland plants for restoration sites	Planting was not possible in 2016, but has concluded in most areas
12. Direct seeding and planting native plants	Investigate effectiveness of direct seeding and planting for banksia woodland establishment	Direct seeding continued 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	Only limited spraying of reserves for weed control was possible in 2016 due to funding delays
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. Collaborations		
16. Community Group and Local Government	Manage high priority sites with community groups and local government	Grants scheme with $300,000 support for 20 community group projects
17. Banksia woodland monitoring program	Measure health of banksia woodlands in Perth using vegetation, groundwater and remote sensing data	Comprehensive monitoring program and remote sensing scientific collaboration established for 6 sites
18. Rare flora monitoring and management	Undertake surveys and manage habitats of rare orchids, especially *Caladenia huegelii*	*Caladenia huegelii* habitat works, translocation and surveys occurred in 2016
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 below)

14. Communication and Outreach in 2016

A. Presentations

Talks for community groups and scientific conferences by Mark Brundrett in 2016 are summarised below. Most of these are about the BWR project, but several concern related topics.

1. Brundrett M. Banksia woodland restoration, weeds and fire. Wildflower Society of WA (9-2-2016).
2. Brundrett M, Longman V, Wisolith A. Three presentations on fire recovery, weed management and restoration of banksia woodland. Banksia Woodland Think Tank Kings Park (18-2-2016).
3. Brundrett M. Recording key ecological information for banksia woodland restoration. Atlas of Living Australia Science Symposium, Kensington (12-5-2016).
4. Brundrett M. Banksia woodland restoration. Jandakot Regional Park Reference Group (12-7-2016).
5. Brundrett M. Restoring banksia woodland: setting criteria, managing problems and comparing methods. Eurardy Reserve Revegetation Workshop. Bush Heritage Australia (19-7-2016).
6. Brundrett M. Banksia woodland restoration, weeds and fire. Friends of Trigg Bushland and Star Swamp (July 31, 2016).
7. Brundrett M. Orchid conservation. WA Native Orchid Study & Conservation Group (19-10-2016).
8. Brundrett M. The global importance of mycorrhizas. Ecological Society of Australia (Dec 1, 1996).

B. Publications and Publicity

Publications and reports in 2016 that are listed in Appendix 1 include:

1. Article on banksia woodland fire recovery for the Land for Wildlife Newsletter (Longman & Brundrett 2006).
2. Interactive website for banksia woodland plant identification and another on pollination (Brundrett 2015ab).
3. Banksia woodland restoration update for Bushland News (Wisolith 2016).

C. Partnerships and Consultation

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

1. Greening Australia WA are joint managers of part of the Forrestdale Lake restoration site.
2. Friends of Forrestdale to plant tubestock, spread seed and monitor restoration areas.
3. Birdlife Australia provided volunteers for planting days in 2013 and 2014.
4. City of Cockburn received funding to manage weeds in Jandakot Regional Park.
5. Banjup Residents Group received seed for growing banksias to plant on private property which was burnt in the 2014 bushfire.
6. Regional Parks received flora and monitoring advice on the Eglinton Estates offset, the Roe Highway Extension project.
7. Advice and seed provided to support the Department of Parks and Wildlife-managed Dundas Road and Lowlands Restoration projects.
8. Western Australian Planning Commission (WAPC) received planting lists and flora advice for revegetation of a cleared WAPC lot at Harrisdale Swamp.
9. Friends of Upper Lesmurdie Falls received further flora advice for their restoration project in the Mundy Regional Park, above Lesmurdie Falls.
10. City of Armadale received planting lists for a sumpland at the Aspiri and Holland Park development adjoining Piara Nature Reserve.

15. References (see Appendix 1 for Reports)

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

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 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.

Jackson K, Brundrett M and Cullity J. 2016. *Strategic Weed Management Plan*. Department of Parks and Wildlife, Crawley, Western Australia.

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.

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 2016.

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 2015.

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.

Resources

Conservation Library	Reports Produced by this project
Naturemap	Flora and vegetation data from this project
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, p. 5. Autumn 2013.

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

Brundrett M. 2015a. Banksia Woodland Plants (an interactive identification guide). (url: www.flickr.com/groups/banksia_plants) (>1300 images with key features).

Brundrett M. 2015c. Banksia Woodland Insects and other Invertebrates. (url: www.flickr.com/groups/perth_banksia_invert).

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 2016. Translocation Proposal *Caladenia huegelii* within the Calleya Development in Banjup. Department of Parks and Wildlife.

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

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.* p. 72. Kwongan Foundation, Perth, Australia.

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 (in press).

Brundrett M and Longman V. 2015. Recovery of banksia woodland after fire. Wildflower Society of WA Newsletter, May 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, Longman V and Clarke K. 2017. *Flora and Vegetation Monitoring Targets for Restoration Areas.* Department of Parks and Wildlife, Crawley, Western Australia. 2017.

Clarke K, Brundrett M, Wisolith A, Sonneman T, Longman V and McMullan-Fisher S. 2017. *Jandakot Airport Flora and Vegetation in the Topsoil Source Area.* Department of Parks and Wildlife, Crawley, Western Australia. 2016.

Clarke K, Glossop B and Brundrett M. 2016. *Site Selection for Topsoil Transfer.* Department of Parks and Wildlife, Crawley, Western Australia.

Collins M, Brundrett M. 2015. Recovery of terrestrial orchids in natural ecosystems after severe disturbance. In: Principles and Practices of Minesite Rehabilitation. Edited by: M. Tibbett. CRC Press. pp 141-158.

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, Bentley. April 2015.

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.

Longman V. 2015. Floristic diversity, density and cover data from 51 quadrats established in primarily upland banksia woodland south of Perth by the BWR Project. NatureMap website (url: naturemap.dpaw.wa.gov.au).

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

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

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 five years after establishment (2012-2016). Species are from the topsoil seed bank, spread from local areas (local opportunist), or from inclusion in planting and seeding lists (total 159).

Species	Topsoil	Topsoil and other	Direct Seeded	Planted 2002 -2015	Local Opportunistic	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 (Baeckea) 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	
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
Desmocladus flexuosus	1			1			
Dianella revoluta				1			
Dichopogon capillipes				1			
Diuris corymbosa	1						2014
Drosera erythrorhiza	1						2016
Drosera glanduligera	1						2012
Drosera macrantha	1						2013

Drosera paleacea	1						2016
*Epilobium hirtigerum**					1		2013
Eremaea asterocarpa			1	1			2013
Eremaea pauciflora	1		1	1			2015
Eucalyptus marginata			1	1			2016
Eucalyptus rudis				1	1	1	
Eucalyptus todtiana			1	1			
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		
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 preissiana				1		1	2015
Melaleuca rhaphiophylla				1		1	
Melaleuca seriata			1	1			2013
Melaleuca teretifolia				1		1	
Melaleuca thymoides	1	1	1	1			2016
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	
Persoonia saccata	1						2016
Petrophile linearis			1	1			2015
Phlebocarya ciliata	1			1			2016
Phlebocarya filifolia				1			
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
Pultenaea reticulata			1			1	
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			
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						2012
Thysanotus manglesianus (sp. climbing)	1						2015
Thysanotus arenarius	1						2016
Thysanotus sparteus	1						
*Thysanotus thyrsoideus**	1						2013
Trachymene pilosa	1						2012
Tricoryne tenella	1						
Wahlenbergia preissii	1						2013
Xanthorrhoea preissii			1	1			
Xanthosia huegelii	1						2013
TOTAL	**113**	**15**	**36**	**69**	**22**		

Appendix 3. Research Collaboration with Murdoch University

Role of Environmental Filters in Restoration of Mediterranean-type Ecosystem of Banksia Woodland

Submitted PhD thesis by Paweł Waryszak (Dec. 2016, supervised by Drs Phil Ladd, Neale Enright and Joe Fontaine).

In this study, three types of environmental filters: dispersal, abiotic, biotic were manipulated to improve understanding of how to successfully re-establish native plant communities. This study was located in banksia woodland - a Mediterranean-type ecosystem restricted to the Swan Coastal Plain in Western Australia that is diminishing due to rapid urban expansion. Here, topsoil from a newly cleared site was stripped, transferred and applied to recipient sites within two months of vegetation clearing. The recipient sites had been grazed for many years prior to purchasing for conservation. Following topsoil transfer, a fully factorial combination of three filter manipulation treatments was applied across the six sites to identify successful restoration techniques. The dispersal filter was tested by altering the volume of topsoil seed bank applied. The abiotic filter experimental manipulation was performed using topsoil ripping. The biotic filter was examined by installing herbivore exclosures.

Emergence and survival of banksia woodland species were quantified in spring and autumn for two consecutive years after topsoil transfer. Overall, the most successful technique was the application of a high volume of unripped topsoil, with resulting mean densities of native perennials of 15.9 ± 0.2 (SE) m^{-2} in the first year. Soil ripping reduced the densities of the emerging native perennials significantly ($t = 4$, $P < 0.001$). Similarly, high volume of unripped topsoil resulted in the highest mean densities of native perennials of 7.6 ± 0.1 (SE) m^{-2} in the second year after topsoil transfer. Application of plot-scale heat treatments in the second year recorded 4.5 % increase in the emergence densities of native perennials ($t = 11.4$, $P < 0.001$). The highest survival through the first summer drought occurred within topsoil ripping treatment in combination with artificial shade (mean survival of 27.3 % ± 5.6 (SE), $t=7.8$, $P<0.001$). High mortality occurred during the second summer drought and overall mean seedling survival over the 2-year sampling period was 2.44% ± 0.2 (SE).

Breaking plant species into key functional groups, the number of non-resprouters oscillated around 70% in both years. Nitrogen-fixers comprised 50% of total native flora richness in the first year after topsoil transfer and decreased markedly to 20% in the second year. Plant assemblages in year two comprised mostly of non-native perennial grasses and perennial, small-seeded native woody shrubs.

The transferred topsoil seed bank contained a close-to-reference species richness of native species propagules, mostly understorey species that suggests a high potential for mitigating environmental barriers on restoration sites but more research needs to focus on improving survival of native seedlings in their early stages of establishment.