Banksia Woodland Restoration Project

Annual Report 4

January - December 2015

Department of Parks and Wildlife

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DOI: 10.13140/RG.2.1.1179.1765

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Acknowledgements:
Thank you to the following volunteers who kindly donated their time to help us with our field work: Monique Anderson, Erika Antal, Zane Bingham, Annie Bone, Emily Cranstoun, Melissa Darling, Paige Featherstone, David James, Lizzy Longman, Katie McLellan, Kelli McCreery, Jim Prince, Nick Suehrcke, Cate Tauss, Natasha Tay and Graham Zemunik. Also, thanks to the following people who helped with plant identification: Una Bell, Rob Davies, Michael Hislop, Greg Keighery, Bronwen Keighery, Russell Barrett.

The recommended reference for this publication is:
Brundrett M, Longman V, Wisolith A, Jackson K, Fielder J, Collins M, Clarke K. 2016. *Banksia Woodland Restoration Project Annual Report 4: January - December 2015*. Department of Parks and Wildlife, Perth.

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 Primer, 2004).
- Rehabilitation – in this report refers to controlling threatening processes in existing native habitat to improve condition (e.g. weed control, access control). Also referred to as "repair".
- 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 and repair existing banksia woodlands, primarily as habitat for the nationally threatened Carnaby's cockatoo (*Calyptorhynchus latirostris*) and the grand spider orchid (*Caladenia huegelii*). Funds from Jandakot Airport Holdings Pty Ltd (JAH) were used to establish the BWR project as part of the Commonwealth's ministerial conditions to offset the impacts from allowing clearing of 167 hectares of native vegetation at Jandakot Airport in Western Australia. Now managed by the Department of the Environment, 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 the offset that supports the BWR project by removing the final deadline for payment of this offset (EPBC 2009/4796, Department of the Environment 2014). This has affected the project's ability to continue works creating new banksia woodland habitat at the restoration sites and undertake long-term management actions in the conservation estate and has also created uncertainty about completion of objectives for the project.

Established in September 2011, the BWR project 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 and condition.

Works undertaken or underway for the BWR project in the first four 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 for banksia woodland biodiversity and condition monitoring over five sites to determine the long term outcomes for banksia woodland weed management and fire.
5. Providing funding, seeds, seedlings and advice to community groups and local governments for banksia woodland restoration at 20 locations.

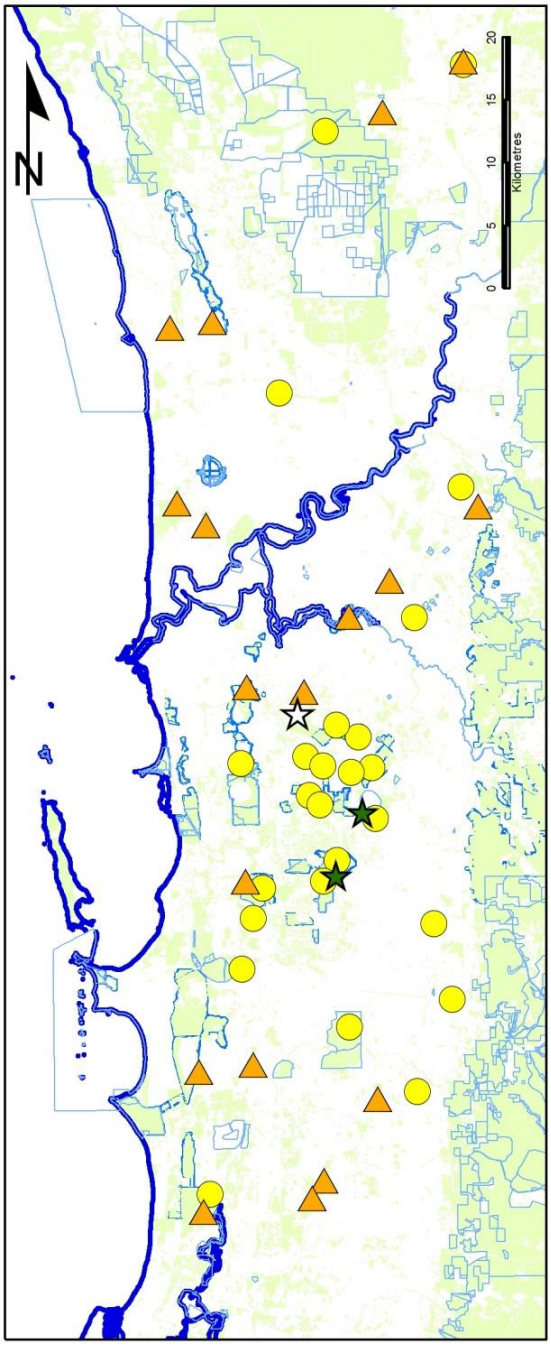
The main aim of restoration work is to establish native vegetation that is self-sustaining and requires minimal management in the long term. Two sites with a total area of 50 ha were selected for restoration of banksia woodland in completely degraded areas dominated by weeds at Forrestdale Lake and Anketell 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 immediately adjacent to the restoration sites.

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 for banksia woodland plants has now 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 provided to other restoration projects or community groups.

Restoration at Anketell Road and Forrestdale Lake included a topsoil transfer in April-May 2012, planting of nursery-raised seedlings from 2012 to 2015 and direct seeding with the support of Greening Australia (WA) in 2012 and 2014 (see Table below). In total, more than 46,000 nursery-raised local provenance native plants were planted. 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. However, the density of native plants was sufficient to meet completion criteria in about 40% of areas restored prior to the summer of 2015/2016. Targets for Carnaby's cockatoo food plants (especially banksia trees) and other native plants were reached in 2015. However, more seeding or planting will be required in 2016 to replace summer losses and infill areas with low understory plant density (16 ha).

In 2015, plant diversity in restoration monitoring plots was about 70% of that measured in reference sites. 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.

Perennial native plant cover increased gradually each year, but was still low (see Graph below). Annual native plants and weeds were initially dominant in restoration areas, but perennial weed cover decreased substantially over time due to weed control (see Graph). Completion criteria targets for the density and diversity of trees and understory plants in restoration areas can be attained for most areas in 2016, provided additional funding is received in time. However, control of threatening processes (e.g. weed invasion) and monitoring will need to continue in the future to ensure a self-sustaining ecosystem develops, which is likely to take many more years.



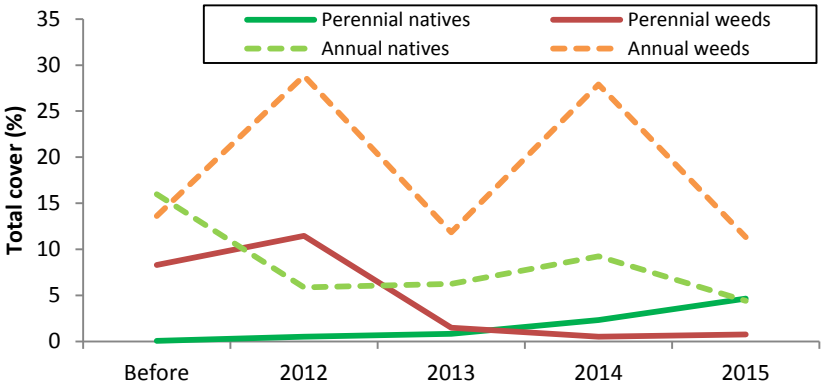
Map *showing Banksia Woodland Restoration Project locations in the Perth Metropolitan Region relative to Jandakot Airport (white star). These include two major restoration areas (green stars), sites for weed management (yellow circles), and funding provided to community groups for the restoration or 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).*

Another key outcome of this work has been 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.

The second major component of the BWR project is to undertake site management works to improve the condition of existing banksia woodland in the conservation estate. Sites for weed control were chosen by selecting areas of good condition banksia woodland under greatest threat after mapping weeds in 23 reserves (1400 ha). Weed control using selective herbicides at 20 locations occurred in 2013 and 2014 (see Map). In total, over 600 ha in 23 reserves were sprayed for perennial veldt grass (*Ehrharta calycina*) and other major environmental weeds. Offset funding was also used to establish a community grants program, the Perth Banksia Woodland Community Restoration Grants, where $300,000 was provided for restoration work, weed management or dieback control at 20 locations (see Map).

Table *showing the extent of each restoration method in hectares at the two restoration sites. *Sub-totals are not cumulative per site as topsoil transfer, planting and direct seeding overlapped in various combinations.*

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	14	0.5	14.5
Total area restored		**39**	**11**	**50**



Graph *showing vegetation cover trends over four 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. The cover of annual natives and weeds is affected by rainfall.*

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). Overall cover was also measured using reference photographs and satellite imagery. Effective weed control initially increased the dominance of annual plants. The response of perennial native plants is slower and will require longer monitoring to determine outcomes. 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 the areas surveyed 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 creating the opportunity to study the response of banksia woodland to hot summer bushfire. We have measured plant diversity, cover and density in the burnt area. There was a 39% mortality rate for banksia trees, but also a very high rate of germination of banksia seed (12,000 per ha) after the fire. More plant species recovered by seed germination rather than by resprouting, but the latter resulted in greater cover. Spraying to control perennial veldt grass before the fire led to a substantial reduction in the cover and density of this grass post fire, while veldt grass cover increased in unsprayed areas after 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 (formerly SEWPAC). In addition to banksia woodland restoration (Condition 4b), the offset also provides funding for acquisition and protection 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 requires 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.

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 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 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 some habitat for the endangered orchid *Caladenia huegelii.* The BWR project has the following principal objectives:

1. Restore banksia woodland by creating and repairing lands 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 by:
    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, but subsequent payments have been delayed by changes in the schedule of clearing at Jandakot Airport. In 2014, the Commonwealth amended the ministerial conditions for the offset, removing a final deadline for any remaining payments (Department of the Environment 2014). Delays in funding relative to the previously agreed schedule (Jandakot Airport Holdings 2010) have affected the continuity, scheduling and resourcing of the BWR project by the Department of Parks and Wildlife. A relatively small area of Jandakot Airport (14 ha) was cleared in 2015, resulting in an interim payment in August 2015 that allowed some restoration activities to continue in 2016. However, a substantial proportion of the offset funding remains to be paid and there is no fixed schedule for this payment or payments. Consequently, it may not be possible for the BWR project to meet all of the original objectives listed above. For example, 60% of restored areas require additional planting or seeding to meet completion criteria targets and all weed management areas require further work to be successful. Offsets are less likely to be effective tools for conservation of biodiversity when there is a discontinuity in funding.

2. Seed Management and Storage

Restoring banksia woodland is difficult because some of the most important species, including banksias, usually do not 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 quality seed, 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.

Seed collected from the Coastal Plain for this project and stored at the TFSC includes large quantities of seed from Jandakot Airport and 52 other locations (Fig. 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 are stored in a refrigerated and humidity-controlled environment to supply nursery orders and direct seeding for the BWR project, as well as other restoration projects (Table 1). Over the life of the project, around 6.4 kg of seed from 49 species have been sent to nurseries, and over 37 kg from 69 species have been used for direct seeding. Currently 850 seed batches from 170 species have been moved into long-term freezer storage, where they will remain available for use by restoration projects.

In late 2014, about 1.8 kg of seed material from 41 species was sent to three nurseries (Table 1), which resulted in over 11,000 tubestock for planting in winter 2015 (Fig. 2, Table 2). Where necessary, species were treated in the TFSC laboratory to promote germination before use in the nursery, by the application of smoke-water, scarification with boiling water, nicking of fruit, application of gibberellic acid, or a combination of these. A seed germination trial using 1440 *Banksia attenuata* seeds was started at Anketell Road in 2015 (Fig. 2A). The purpose of this trial, which is currently underway, is to try to increase the speed and reliability of banksia seed germination in the field.

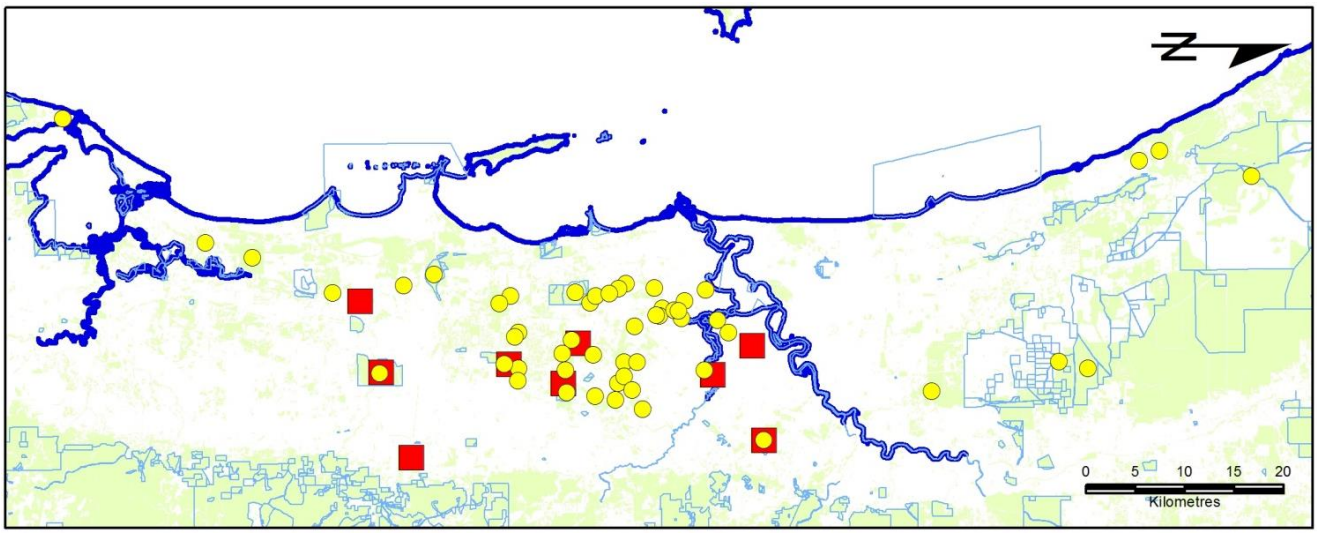

Figure 1. Seed collecting locations (53 sites: yellow circles), and sites where seed has been used for restoration (nine sites: red squares).

Table 1: Seed batches processed, quantified and tested at the TFSC for the BWR project from August 2014 to January 2016, and the total across the five years of the project from 2011 to 2016.

	August 2014 – January 2016		TOTAL 2011-2016	
	Number of Batches	**Number of Species**	**Number of Batches**	**Number of Species**
Received	308	74	1212	122
Quantified	490	135	1261	151
Germinated	378	76	613	87
Nursery orders	134	41	341	49
Seed given to other projects	148	64	167	59
Direct seeding orders	-	-	318	69

Figure 2. A. (Left) Germinating seed of *Banksia attenuata* at Anketell Road, showing impacts of invertebrate grazing on its cotyledons. **B**. (Right) Some of the nursery-raised seedlings of banksias that were planted in 2015.

3. Production of Nursery Seedlings

Nursery seedling quality and hygiene specifications for disease control were rigorously defined in a panel tender, from which three nurseries were used in 2015. In 2015 about 11,000 seedlings were received, including 5846 tree seedlings and 3551 banksia seedlings (Table 2, Fig. 2B). For the first three years of restoration at Anketell Road and Forrestdale Lake, nursery orders primarily consisted of trees and shrubs with canopy stored seed that were unlikely to regenerate from topsoil. In 2014 and 2015, nursery orders were based on monitoring data from restoration sites and targeted species required for infill plantings to reach completion criteria targets. In 2015 planting was undertaken by staff and volunteers, due to limited availability of staff and funding.

Figure 3. A. (Left) Planting day with Regional Parks staff and Aboriginal Trainees at Anketell Road in June 2015. **B.** (Right) The Friends of Forrestdale and project staff at a planting day in June 2015.

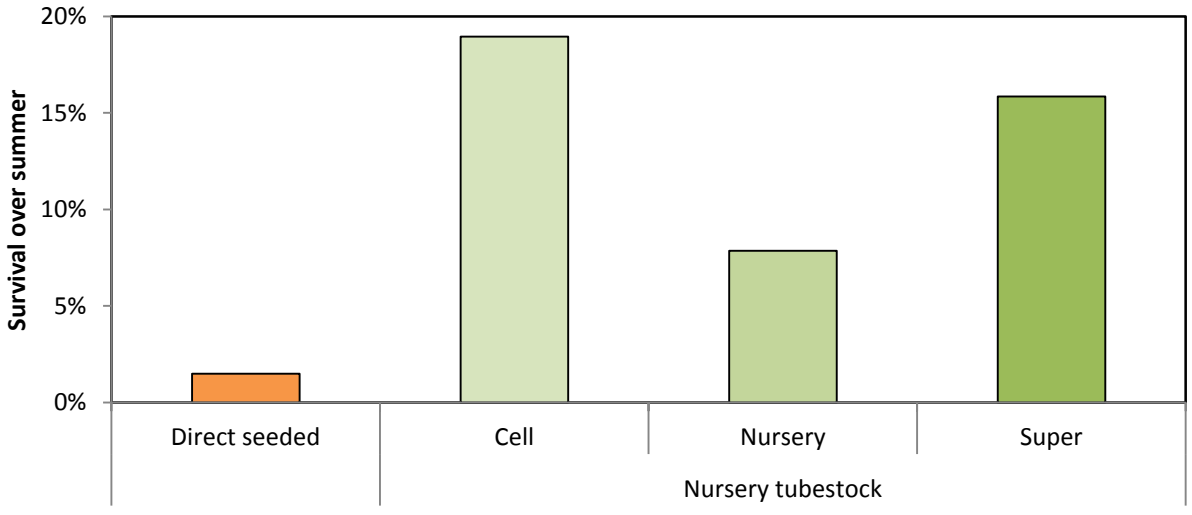

Figure 4. Survival over summer of *Banksia attenuata* plants planted or direct seeded in 24 plots in early July 2014. The graph shows the percentage survival from spring 2014 to autumn 2015. There were three container sizes for the planted nursery tubestock, cell trays (smaller size), nursery tubes (standard size), and super tubes (larger size). Survival of seedlings was very low in the summer of 2014/2015 due to severe summer drought (the rainfall deficit for the time of this trial was 127 mm).

Table 2. Nursery-raised seedlings planted in 2015.

Species	Anketell Road	Forrestdale Lake	Pony Place	TOTAL
Acacia huegelii	204	35		239
Acacia pulchella	218	27	20	265
Acacia saligna	167	27		194
Allocasuarina fraseriana	274	6	20	300
Allocasuarina humilis	214	38		252
Anigozanthos manglesii	110	21		131
Banksia attenuata	1643	290	150	2083
Banksia menziesii	1209	258		1467
Bossiaea eriocarpa	36	4	20	60
Calothamnus lateralis	191	3	30	224
Conostylis aculeata		14		14
Corymbia calophylla	151	2	10	163
Dianella revoluta		9		9
Eremaea asterocarpa	105	18		123
Eremaea pauciflora	78	18		96
Eucalyptus marginata	460	61		521
Eucalyptus rudis	455	9	15	479
Eucalyptus todtiana	156	27		183
Gompholobium tomentosum	40	8		48
Hemiandra pungens	33	7		40
Hibbertia huegelii		5		5
Hibbertia subvaginata	63	12		75
Hypocalymma angustifolium	24	5		29
Jacksonia furcellata	60	12		72
Kennedia prostrata	88	22		110
Lechenaultia floribunda	60			60
Lepidosperma squamatum	173	23		196
Melaleuca preissiana	611	9	30	650
Melaleuca rhaphiophylla	845		30	875
Melaleuca seriata	517	56	40	614
Melaleuca thymoides	477	46	20	543
Patersonia occidentalis	90	13		103
Pericalymma ellipticum	64	32		96
Regelia ciliata	89	1	20	110
Regelia inops		144		144
Stirlingia latifolia	111	19		130
Xanthorrhoea preissii	458	56	20	534
GRAND TOTAL	**9474**	**1337**	**425**	**11,236**

Table 3. Total number of nursery-raised seedlings planted over three years at Anketell Road, Forrestdale Lake and a smaller restoration area in Anketell North (Pony Place).

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**

4. Restoring Banksia Woodland using Topsoil Transfer, Planting and Direct Seeding

At both Anketell Road and Forrestdale Lake, topsoil from Jandakot Airport was spread to a uniform depth of either 50 or 100 mm in April-May 2012 after a thin layer of existing topsoil was scraped off to reduce weed soil seed bank. Planting and direct seeding was started in 2012 with larger planting and seeding programs from 2013 to 2015, as explained below (Table 4). At both Forrestdale Lake and Anketell Road, 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. 2016). Topsoil from Jandakot Airport was only applied to upland areas, as it contained seeds of species unsuited to dampland habitats.

There were substantial deaths of planted tubestock, especially banksias, over the summer of 2014/2015 (Fig. 4). Plantings in 2015 redressed these losses and allowed completion targets for banksia trees and other trees and shrubs to be reached, but it is anticipated that more trees may be required in 2016 to replace further summer losses. In total, 11,236 nursery-raised native plants were planted in 2015 (Table 3). Tubestock was planted by Parks and Wildlife staff, members of Friends of Forrestdale, and Green Army crew members. A staff planting day was held on the 19th of June at Anketell Road, with 19 staff from Regional Parks and Swan Region attending (Figs 2, 3). 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 5, 6).

In total, 46,459 nursery-raised native plants were planted over four years (2012-2015) at Anketell Road, Forrestdale Lake, and Pony Place, a small restoration area in Anketell North (Table 3). Over 2012-2014, 14.5 ha at Anketell Road and Forrestdale Lake were direct seeded for the BWR project by Greening Australia WA to establish some of the key banksia woodland species. Seed drill technology was used to restore large areas efficiently. 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. Figures 5 and 6 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.

Work to manage weeds in restoration sites is ongoing, with perennial species targeted due to their invasiveness and competitive ability. Perennial veldt grass was sprayed using a grass-selective herbicide from 2012 to 2014. Other invasive weeds (all bulbs, *Euphorbia, Pelargonium*, *Carpobrotus*, *Lupinus,* etc.) were removed by hand each year including 2015.

In 2015, a research trial was set up to assess the best method of establishing banksia trees from seed in restoration sites (Fig. 2A). *Banksia attenuata* seeds were planted in four plots across Anketell Road. Half of the seeds were pre-soaked in water, while the other half were untreated. In addition, two seeding times (June and July) were compared. From October onwards, a small subset of the seeds in each plot was watered every one to three weeks, depending on the amount of rainfall received on site. These results will be assessed in 2016.

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
	TOTAL	14	0.5	14.5
Fencing	2012	10	3.5	13.5
	2014	13	-	13
	TOTAL	23	3.5	26.5
Total for all activities		**39**	**11**	**50**

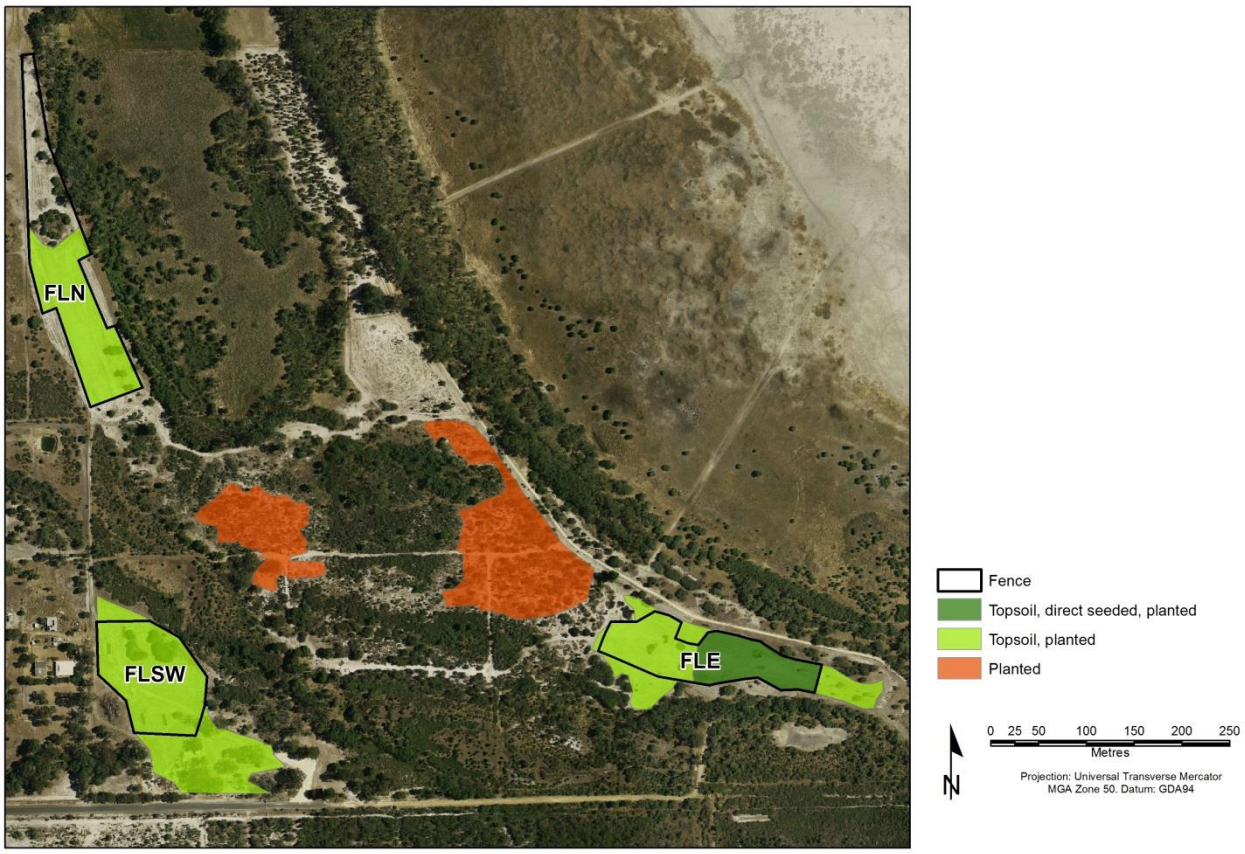

Figure 5. Forrestdale Lake restoration site showing total areas fenced, direct seeded and planted from 2012 to 2015. Three separate management areas with spread topsoil are labelled.

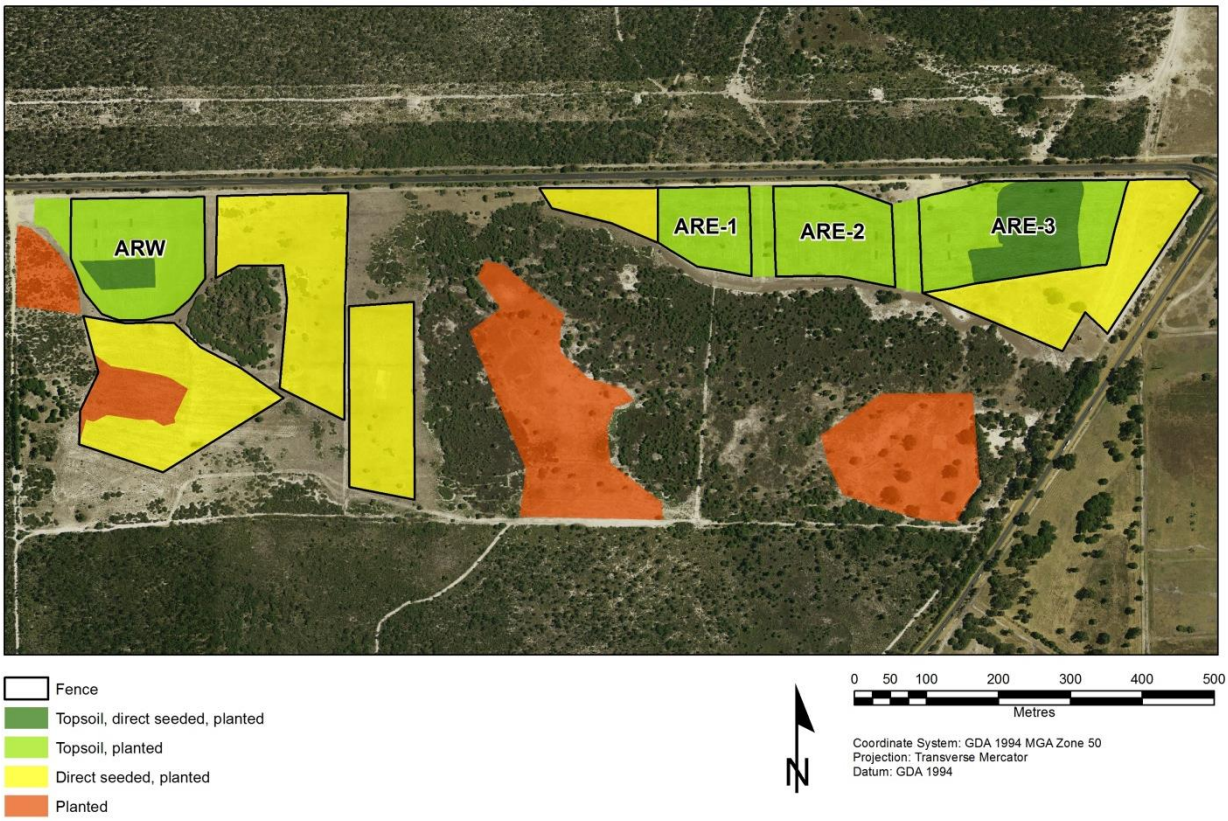

Figure 6. Anketell Road restoration site showing total areas fenced, direct seeded and planted from 2012 to 2015. Four separate management areas with spread topsoil are labelled.

Figure 7. Vegetation at Anketell Road after four years of restoration work. **A**. An area with typical plant cover in early 2015. **B**. Trees resulting from direct seeding and planting that occurred in 2014. **C**. Large shrubs were more dominant in many areas by late 2015. **D**. A group of cowslip orchids (*Caladenia flava*). **E**. *Lechenaultia floribunda*.

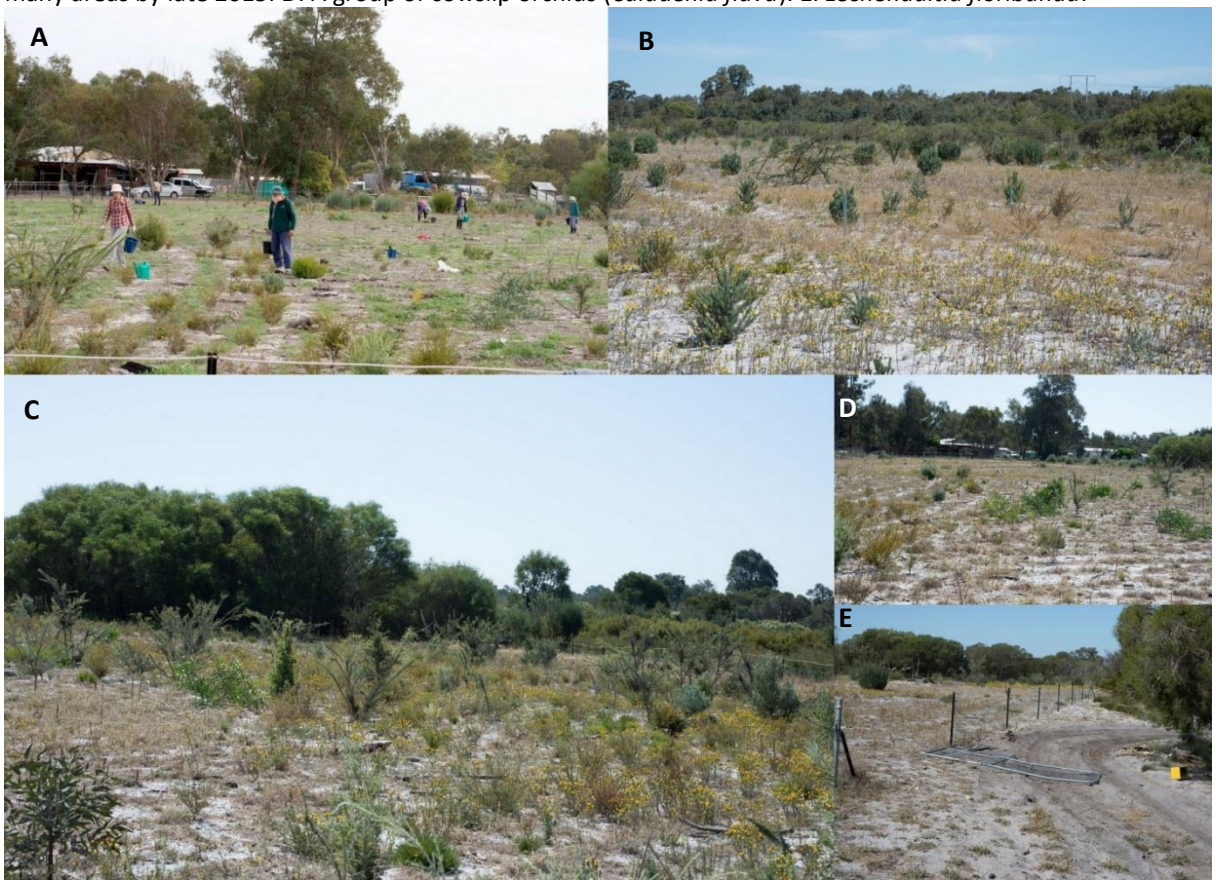

Figure 8. The Forrestdale Lake site four years after restoration commenced. **A**. The Friends of Forrestdale at a planting day in June 2015. **B-D**. Variations in plant cover. **F**. Vandalism to fencing and gates was common in this area.

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 (Appendix 1). The cover and density of all species was measured within 1 x 1 m 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 5 x 5 m 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 10 x 10 m 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 5 x 5 m to 50 x 50 m at Anketell Road. This grid of plots also includes twelve 25 x 25 m plots that will be used to measure tree canopy cover. 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 (Figs. 9, 10). A rapid decline in rainfall in spring was also observed to substantially increase the mortality of seedlings and planted tubestock at restoration sites in 2012, 2013 and 2015.

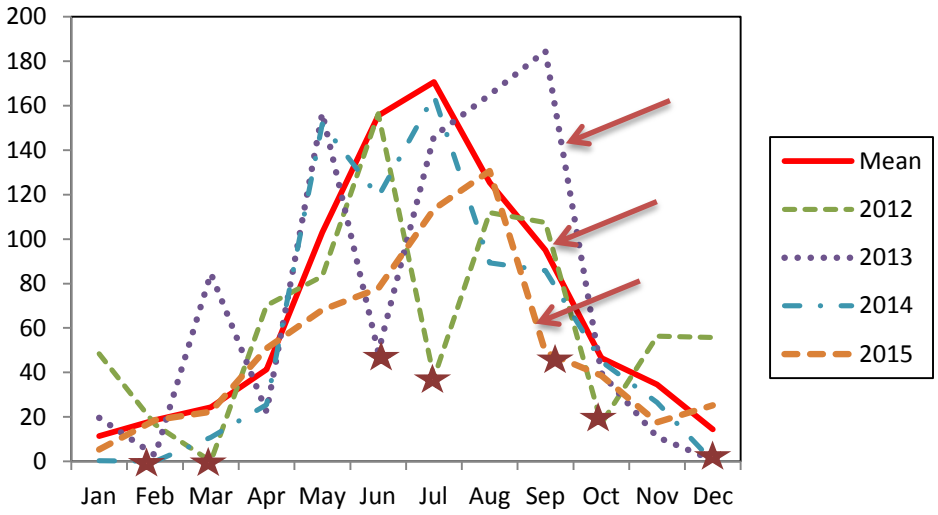

Figure 9. Rainfall (mm) at the Anketell Road weather station from 2012 to 2015 (www.bom.gov.au). Steep declines in rainfall in spring (arrows) had a major impact on plant survival in combination with periods of autumn, winter and/or spring drought each year (stars). The mean is a long-term average.

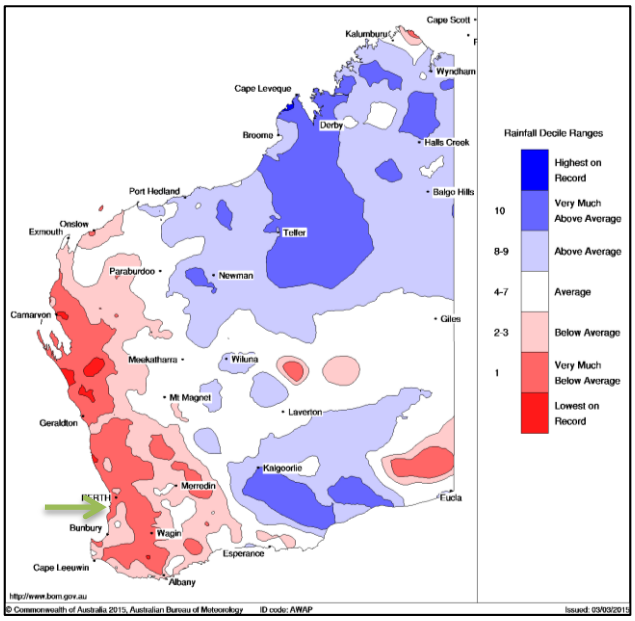

Figure 10. Rainfall Deficit Map (www.bom.gov.au) for the first three years of the BWR project (March 2012 to February 2015). The Anketell Road site (arrow) is within the "very much below average category". The total rainfall deficit for the period from 2012 to 2015 was 380 mm.

5.2. Plant Cover

To measure the abundance and cover of all species, we monitored 113 of the 1 m^2 plots across the sites each year to compare species present initially with those emerging from the topsoil. These plots are arranged along six transects at Anketell Road and nine at Forrestdale Lake and provided the following results:

- The average cover of perennial native species has increased gradually, while perennial weeds have substantially declined as a result of weed control (Fig. 11AB). Cover of annual weeds and annual native plants was initially much higher than perennial species but varies from year to year.
- The cover of weeds was very high before topsoil was applied and is gradually reducing, primarily due to perennial weed control (Fig. 11AB).

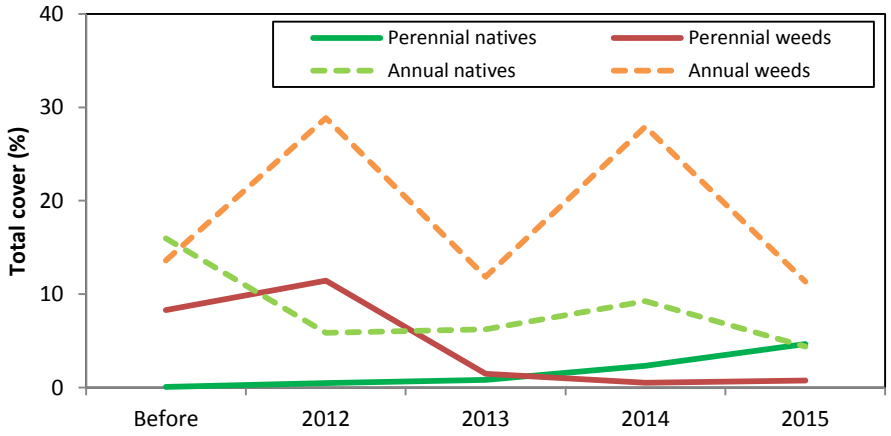

Figure 11A. Changes in the cover of different categories of plants at the Anketell Road restoration site. Results are from before work commenced and for the first four years after topsoil was spread and planting and seeding of native plants commenced. Native annual plant cover at this site is dominated by *Podotheca gnaphalioides,* a native disturbance opportunist.

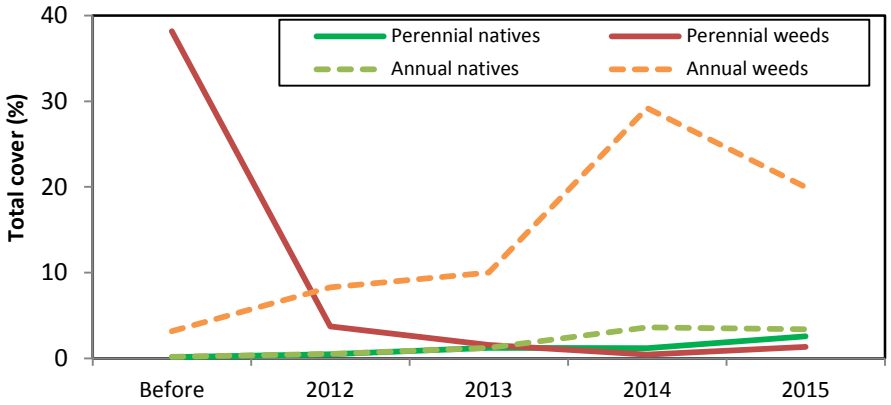

Figure 11B. Changes in the cover of categories of plants at the Forrestdale Lake restoration site over the first four years. There were fewer annual native plants and annual weeds at this site initially. Weed control has greatly reduced the cover of perennial weeds (predominantly veldt grass).

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 included over 500,000 annual native plants, as well as about 170,000 small perennial native plants per hectare, many of which did not survive severe drought in summer. Survival of nursery-grown seedlings planted on site was also low due to some of the driest summers on record (Section 5.1), but a substantial number were still alive in 2015 (about 263 stems per hectare). By late 2015, there were about 11,500 native perennials, many of which were from the topsoil, per hectare (Fig. 12), which was still sufficient to meet restoration targets in most areas (Table 5).

Perennial native plant density is dominated by understory plants growing from the respread topsoil. These include many shrubs and herbs as well as geophytes, which grew from seed and from tubers or roots transferred in topsoil (Appendix 2). After planting to replace missing trees and perennials in 2015 (Table 2), plant density was adequate, except at several areas at Anketell Road and one at Forrestdale Lake that will require additional planting or seeding in 2016 (Fig. 12). The density of trees reached target levels in most areas in 2015, but some of these trees will not survive over summer (Fig 13, Table 5).

The density of weeds was very high initially at one to two million stems per hectare and is slowly reducing. Several weed species were widespread across the site but each had less than one per cent average cover (Fig. 14). These species were managed by hand weeding in 2015, as explained above and in Section 6.

Direct seeding of 12 ha by Greening Australia in 2014 at Anketell Road occurred in areas shown in Figure 6. This resulted in substantial numbers of banksias, eucalypts and shrubs, but overall plant densities are much lower compared with recruitment from topsoil (Fig. 7B). Planting of tubestock also occurred in these areas at Anketell Road, which are shown in Figure 6. These areas did not receive topsoil from Jandakot Airport, so have lower diversity and density targets for understory plants, but overstory targets are the same as in other areas. We plan to apply additional seed in areas with low plant density in 2016. Most of the areas with low plant density were direct seeded without applied topsoil (12 ha at Anketell Road). There are also areas with applied topsoil that have lower plant density, as shown in Figure 12.

Additional monitoring results will be provided by Pawel Waryszak, a PhD student at Murdoch University, who measured recruitment from topsoil-stored seed from 2012 to 2014. It is expected that his work, which was funded by this project, will be published in 2016.

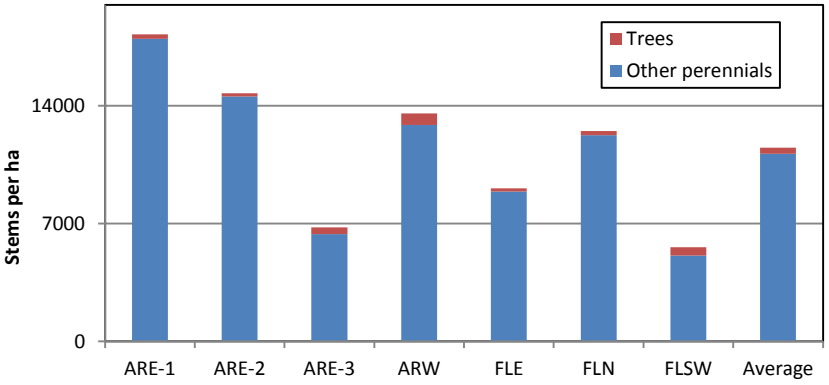

Figure 12. The average density of all native plants and weeds at the Anketell Road and Forrestdale Lake restoration sites measured in October 2015 (data from 80 plots of 5 x 5 m). These results do not include seedlings, annual natives or weeds (AR = Anketell Road, FL = Forrestdale Lake, E = east, W = west, SW = southwest - see Figures 5 and 6 for locations). Most areas are above set targets for plant density (7000 stems per ha).

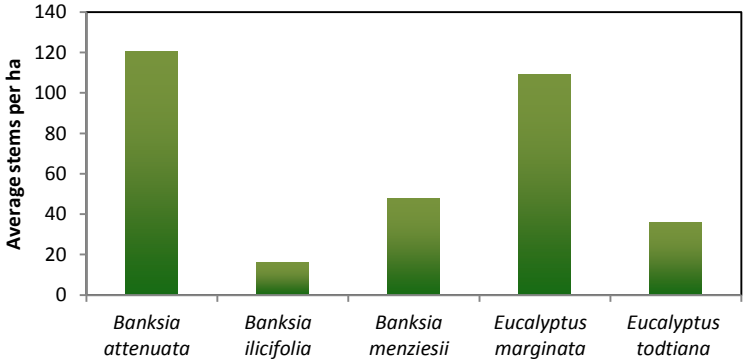

Figure 13. The density of trees in twelve 25 x 25 m monitoring plots at Anketell Road. The total density of all trees was about 400 stems per hectare and there were approximately 300 stems per hectare of banksia trees in these plots.

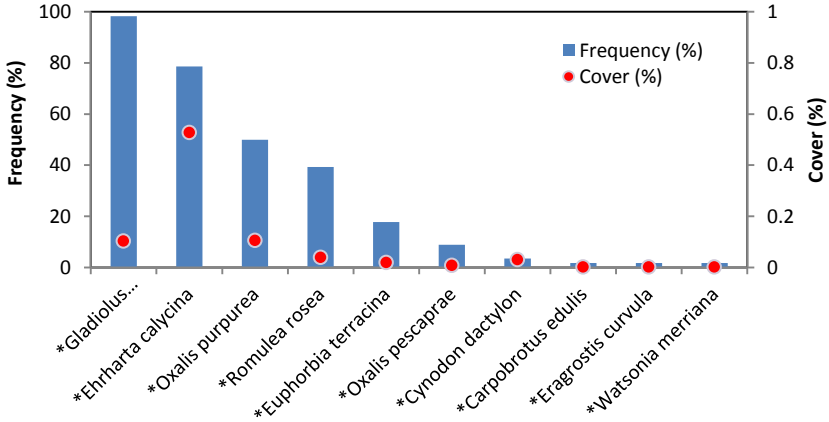

Figure 14. Frequency and cover of perennial weeds in the Anketell Road 5 x 5 m quadrats (spring 2015). While some weeds were widespread, their cover was very low (each < 1%). Results are from 56 plots in total. Red dots show total cover (scale on right).

5.4. Plant Diversity

After only three 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 10 x 10 m plot equivalents is approaching targets based on reference plots after three years (Table 5). The majority of native species from Jandakot Airport reference plots have germinated from topsoil in the restoration sites, or are included in the list of planted or seeded species. However, some key differences were also noted, including 20 or more species observed in restoration sites, but not in surveys of the area where topsoil was harvested. These include local opportunists that spread from adjacent areas (Fig. 15), 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 such as species of *Austrostipa, Podotheca* and *Trachymene* and small shrubs such as *Hibbertia subvaginata* and *Bossiaea eriocarpa*. These plants were initially abundant, declined in numbers by year three, but are still relatively common. Larger shrubs that are also very common in restored areas include *Adenanthos cygnorum* and *Jacksonia furcellata* (e.g. Fig. 7). These species have key roles during vegetation establishment, but often senesce within a few decades, remaining 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 have not yet been observed in restored areas. There are over 80 species of weeds present in the restoration areas, the majority of which are of limited concern; for example, small annuals weeds which are shade intolerant so are expected to diminish in importance with time.

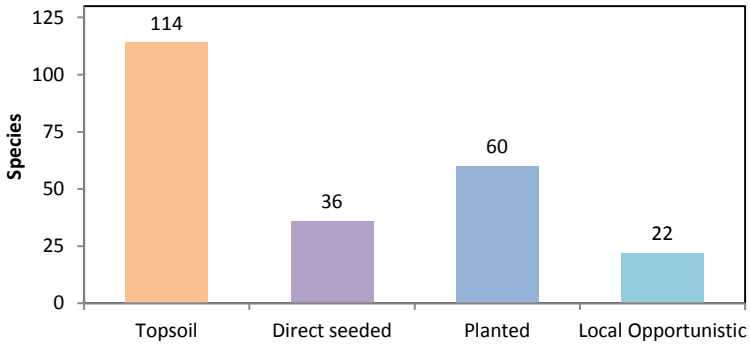

Figure 15. The relative proportions of native plants recruited from different propagation sources. There is some overlap between categories, especially for planted and direct seeded species. There are 160 species in total, which are listed in Appendix 2.

5.5. Restoration Outcomes Relative to Targets

Restoration outcomes relative to completion targets are summarised in Table 5. After three 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 (Fig. 8). As illustrated in Figure 15, 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. 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 2016. Additional planting and seeding is required in most areas without topsoil (17 ha). It is expected that differences between revegetated and reference sites will continue to reduce over time as native plants grow and gradually supress the shade intolerant annual weeds that are currently very common. Ecosystem functional targets were also assessed and 82 plant species flowered in the first four years, of which many were perennials (Fig. 16). Substantial pollinator activity and seed set were observed at both restoration sites.

A key objective of this project is to evaluate the relative cost effectiveness of different methods for restoration of banksia woodland. Data gathered for this purpose include the density, diversity, survival and growth of plants recruited from topsoil, direct seeding and planting and the cost per plant resulting from each method. Preliminary cost estimates are provided in Appendix 3. 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 cases, since it requires topsoil source areas to be free of major weeds and 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 2015 and will decrease due to drought in the 2015/2016 summer.

Criteria	Target	Status in late 2015
Total species richness	Maximise native species richness *There were **>80 species** present in reference quadrats*	About **160** native species (highly variable spatially)
Average species richness per 10 x 10 m 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).*	**14 to 30** species per quadrat (average 24)
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	**428** per ha
Carnaby's cockatoo food plants	This consists primarily of banksias - **250** stems per ha	**290** per ha (banksia only)
Average understory species richness per 10 x 10 m 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).*	**14 to 28** native species per plot (average 22) in topsoil areas (lower elsewhere)
Total density of native perennial plants	Establish **7,000** stems per ha	**4,000 - 22,000** stems per ha (average 13,000)
Annual native plants	No target set and very much lower in reference sites	**>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
Weed cover	Manage serious weeds, especially perennials, monitor annual weeds and manage if necessary	Perennial weeds effectively managed, but annual weeds are common (Fig. 11)

5.6. Ecological interactions

A. Flowering, Pollination and Seed Set

Over half of the native species flowered by year four (Fig. 16). Larger plants, especially trees, required longer to flower. Flowering of *Banksia menziesii* commenced in 2015, but is not expected to become common for several more years. Plants that flowered prolifically in 2015 included species of *Jacksonia, Lechenaultia, Melaleuca and Kunzea*, as wells as native orchids such as *Caladenia flava* (see Fig. 7). Pollinators were commonly observed at the restoration sites from year two onwards, especially in spring and summer (Fig. 17).

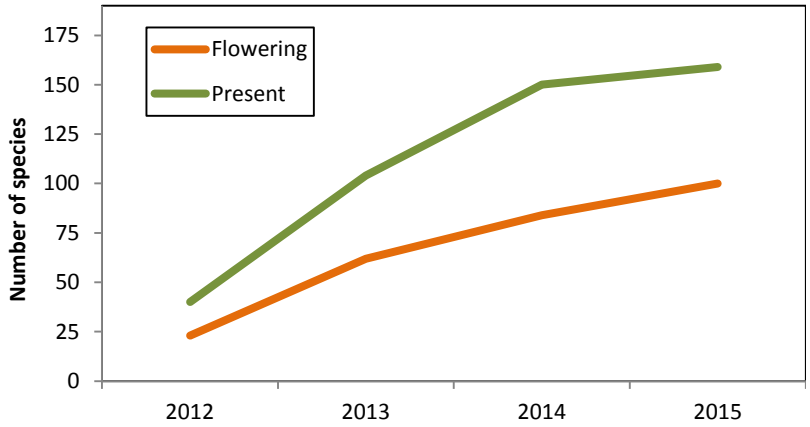

Figure 16. Increases in the number of plant species present and flowering at both restoration sites over the first four years after topsoil transfer. These totals also include species that were planted or direct seeded. Species are listed in Appendix 2.

B. Grazing, Parasites, Fungi, etc.

Examples of harmful interactions that were observed include grazing of banksia seedlings by invertebrates (Fig. 18). Portuguese millipedes (*Ommatoiulus moreleti*) and grasshoppers (especially nymphs of *Urnisa* sp.) were the most commonly observed grazers and the former were often abundant under capeweed

(*Arctotheca calendula*) plants. This seems to be an example of facilitation of grazing of native plants by an alien invertebrate (Portuguese millipede) which is sheltered by an alien weed. Examples of beneficial interactions include:

1. Broomrape (*Orobanche minor*) was a common parasitic plant in restored areas and primarily attacks weeds. This resulted in reduced vigour of capeweed in some areas.
2. Mycorrhizal and saprophytic fungi were observed to fruit in restored areas and a smut fungus that attacks veldt grass was also observed in these sites.

By year four there was some 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 should have produced sufficient seed to replenish the topsoil seed bank.

Figure 17. Examples of pollinators at restoration sites. Some pollinators were associated with existing *Eucalyptus todtiana* trees, but most are on newly established shrubs such as *Jacksonia, Lechenaultia* and *Acacia* spp. The most common pollinators were small brown native scarab beetles in the genus *Neophyllotocus*, shown on capeweed and *Podotheca gnaphalioides* (a native daisy) in the last two photos of row 4.

Row 1 - native bees

Row 2 - wasps

Row 3 - flies and butterflies

Row 4 - beetles

Figure 18. Ecological interactions at restoration sites.

Row 1 - termites, wood rotting fungus, mycorrhizal fungus (*Pisolithus* sp.) and galahs eating weed seeds.

Row 2 - smut fungus on veldt grass, broomrape parasitising capeweed, antlion and jumping spider.

Row 3 - examples of grazing by invertebrates.

Row 4 - pigface, a major weed spread in kangaroo dung, galls on *Acacia saligna*, banksia seedling grazing by invertebrates, banksia sapling grazing by kangaroos.

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 also identified where fencing and gates are required to control illegal access and rubbish dumping (Table 6). This will also reduce the spread of weeds and *Phytophthora* dieback by off-road vehicles in these reserves. 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. Select weed species to maximise ecological benefits.
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.

Over 900 ha of banksia woodland was mapped using a differential GPS to determine the cover and distribution of high priority weed species for the BWR project, in addition to about 500 ha mapped previously by our staff and several sites mapped for the City of Cockburn. Following weed mapping a strategic prioritisation process using the objectives listed above was used to select the sites and weed species to target. Perennial veldt grass was the weed species with the widest distribution, and approximately 360 ha and 322 ha of land was sprayed to control it in 2013 and 2014, respectively. In most cases there were clear benefits visible within a few weeks, as suppressed native plants became visible (Fig. 19). 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.

Weed management commenced in 2013 and continued in 2014 for perennial veldt grass and other highly invasive weeds. We were unable to respray areas in 2015 due to funding issues described in section 1.1. It will be necessary to respray these areas in future years to ensure weeds do not regain dominance from surviving individuals or seed, but this is dependent on availability of funding. In total, 20 bushland areas and two restoration sites had weed control works funded and managed by the BWR project in 2014 (see Fig. 21 and Table 6):

1. The two restoration sites, Anketell Road and Forrestdale Lake, were sprayed to manage perennial veldt grass and other major weeds including broad-leaved annuals. Hand removal or spraying of lupins (*Lupinus* spp.), pigface (*Carpobrotus edulis*), watsonia (*Watsonia meriana* var. *bulbillifera*), Geraldton carnation weed (*Euphorbia terracina*), woody weeds such as *Acacia* spp. and Victorian tea-tree (*Leptospermum laevigatum*) and arum lily (*Zantedeschia aethiopica*) also occurred at these sites.
2. A total of 360 ha were sprayed primarily for veldt grass control. These areas, which are in Regional Parks and other reserves (Anketell Road North, Anstey Keane, Harrisdale Swamp, Kogolup Lake, Piara Nature Reserve, Shirley Balla Swamp and The Spectacles).
3. Weed control to manage outbreaks of other major weeds including Sydney golden wattle (*Acacia longifolia*), watsonia, freesia hybrids, Geraldton carnation weed and arum lily also occurred at the same reserves (Table 6). Additional follow-up spraying for these weeds was organised following the fire in Shirley Balla, as well as hand weeding by a Green Army team in 2015.
4. A total of 90 ha of veldt grass were sprayed in Swan Coastal District reserves (Hawkevale Bushland, Leda Nature Reserve, Mirrabooka Bushland and Watkins Road Nature Reserve).
5. The BWR project funded the City of Cockburn to spray a total of 8 ha for veldt grass and Geraldton carnation weed in Denis de Young and Rose Shanks Reserves.
6. A dolichos vine (*Dipogon lignosus*) outbreak at Harrisdale Swamp that was smothering trees was first managed in 2013 by cutting down vines and herbicide. Follow-up work by staff is ongoing.

7. Where possible, small outbreaks of weeds that provided a major threat to nature reserves have been dealt with by staff or contactors. These weeds include opuntioid cacti and other succulents, pampas grass (*Cortaderia selloana)* and eastern-states' eucalypts.

Weed management focussed on perennial weeds which are highly competitive with native plants. In addition to perennial veldt grass, Geraldton carnation weed, freesia hybrids, babiana (*Babiana angustifolia*), cape tulip (*Moraea flaccida*), yellow soldiers (*Lachenalia reflexa*), watsonia, arum lily, tree tobacco (*Nicotiana glauca*) and woody weed species have been targeted in some sites (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). 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%. Weed control in 2013 and 2014 met these standards in most cases, with a total of 500 ha managed. The dolichos vine control in Harrisdale Swamp has been controlled sufficiently for Conservation Employees working for Regional Parks to be able to effectively manage it within their works programs.

Fencing funded by the BWR Project is listed in Table 6. This included 8.3 km of rabbit-proof fencing at Anketell Road and Forrestdale Lake restoration sites. In addition, 7.5 km of fencing was installed by Swan Coastal District to protect banksia woodland at Melaleuca Park, Fraser Road and Greater Brixton Street Wetlands, as well as three nature reserves (Leda, Hawkevale and Cardup).

As shown in Figures 19 and 20, weed spraying had a major impact on veldt grass cover at most sites. Unfortunately spraying could not be continued in 2015 due to offset funding delays, and by spring 2015 veldt grass cover was increasing and flowering was observed at one site. Veldt grass recovery was most substantial at Shirley Balla where part of the site was not sprayed in 2014. Perennial veldt grass control is most effective if there are three continuous years of spraying.

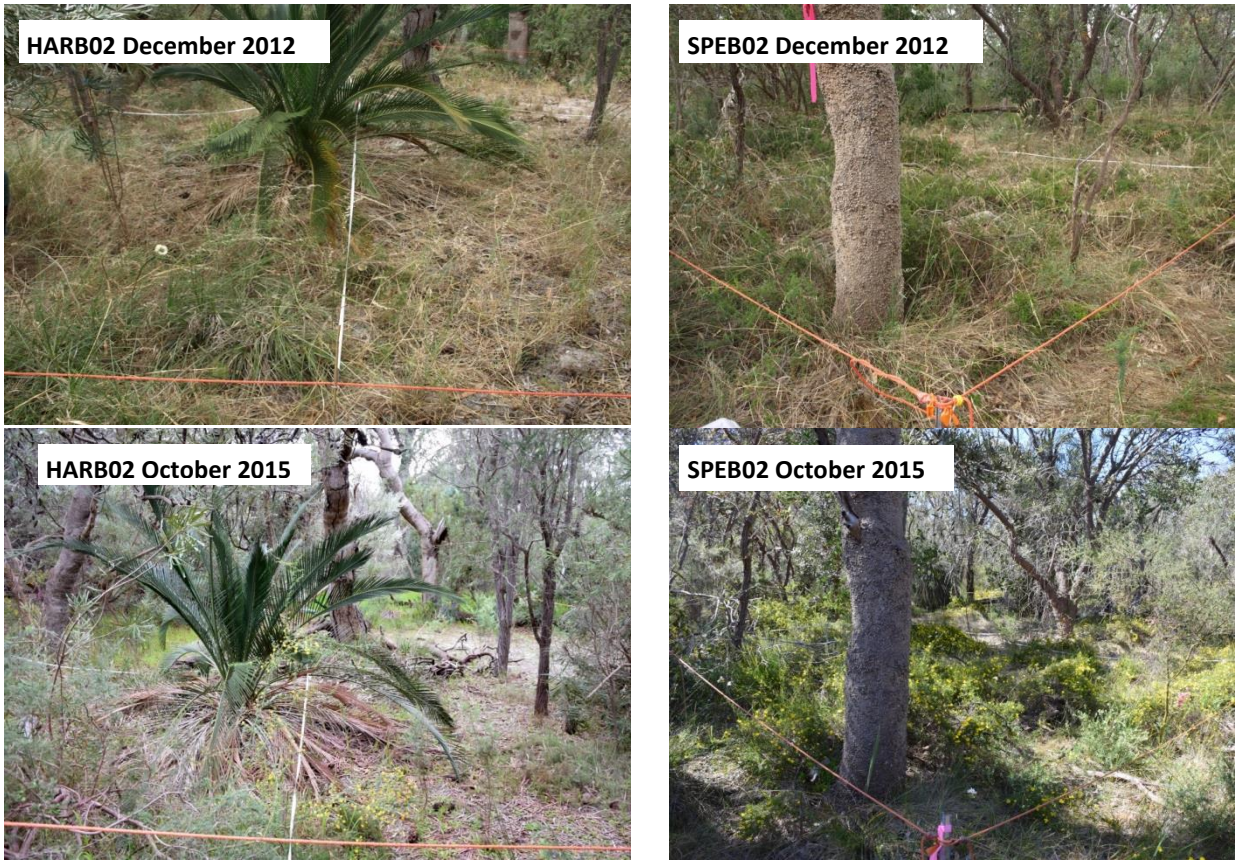

Figure 19. Monitoring plots before and after spraying to control veldt grass at Harrisdale Swamp (HARB02) and The Spectacles (SPEB02).

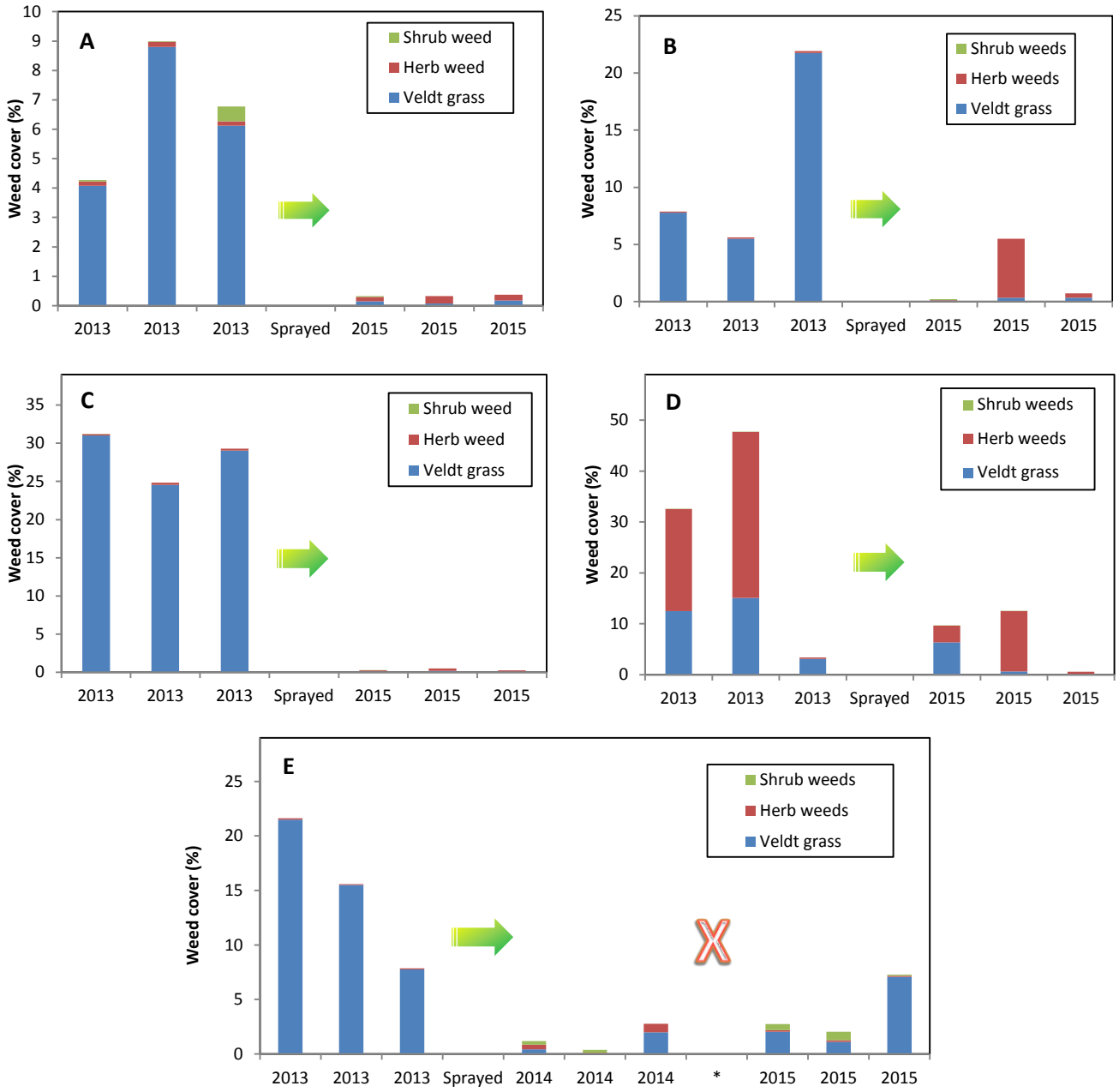

Figure 20. Weed control outcomes for perennial weeds shown for three monitoring plots before (2013) and after weed management (2015). Within each graph, the same three plots are shown before (2013) and after (2015) weed control, so there were 15 plots in total at five sites. All sites were sprayed for veldt grass in 2013 and 2014 (green arrows), except for Shirley Balla Swamp (E), where spraying did not occur in 2014 (X). Spraying with grass-selective herbicide for veldt grass control was very effective in all plots that were sprayed twice in consecutive years. Herbaceous weeds became more dominant after veldt grass control in one plot at The Spectacles (B), but not elsewhere. Perennial (shrub) weeds only became more dominant in 2015 at Shirley Balla Swamp, and this was due to the fire. For data on the cover of annual weeds after spraying, see Figures 22 and 23.

Key: A = Harrisdale Swamp, **B** = The Spectacles, **C** = Kogolup Lake, **D** = Rose Shanks Reserve, **E** = Shirley Balla Swamp.

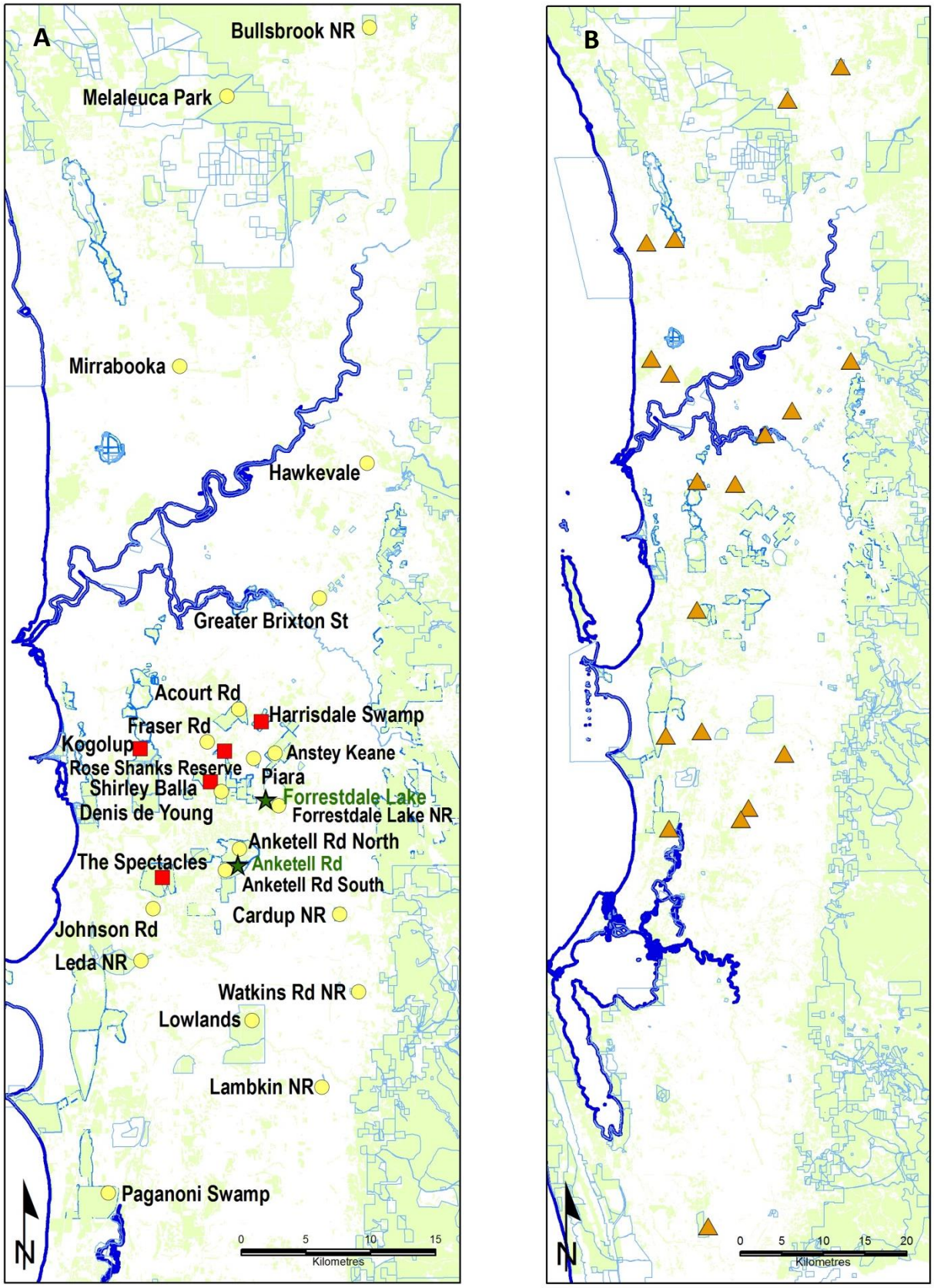

Figure 21. A. Areas where weed management funded by the BWR project occurred from 2012 to 2014 (yellow circles). Perennial veldt grass control sites with monitoring plots are shown as red squares. Restoration sites are shown as green stars. **B.** Locations of projects funded by Perth Banksia Woodland Community Restoration Grants (see Table 8).

Table 6. List of sites for weed control, fencing and other actions managed and funded by this project.

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	Spraying - 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 and Sydney golden wattle, tree tobacco
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 10 x 10 m plots in five reserves where weed management is underway (Fig. 21A). This monitoring framework was initially established to monitor the response of native plants to the control of perennial veldt grass (*Ehrharta calycina*), the most dominant environmental weed at these sites. These plots are used to monitor plant diversity, density, cover and tree canopy health, as well as fauna diversity (Section 9). Photographs of two of these plots, both before and after weed spraying can be seen in Figure 19, showing an increase in the visibility of native plants after veldt grass is eliminated. Orchids were one of the first groups of native plants to respond to weed management, presumably due to their wind-dispersed seeds. The overall dominance of perennial weeds substantially decreased after spraying removed most perennial veldt grass (Fig. 22) and other weed management activities removed other perennial weeds (e.g. freesia hybrids and Sydney golden wattle). The main initial response to veldt grass control was increased dominance of small annual native plants such as *Trachymene pilosa* and annual weeds such as flatweed (*Hypochaeris glabra*) and *Ursinia anthemoides* (Fig. 23). There were fewer annual weeds in 2015 than in 2014, perhaps because of lower rainfall (Fig. 9). Small annual weeds are not considered to be of major concern, as they are smaller in stature than most native plants.

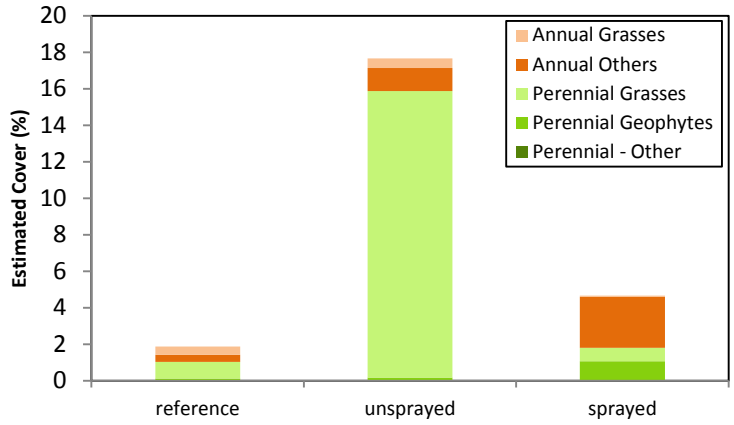

Figure 22. The average cover of annual and perennial weeds in 24 weed management study plots in 2015. Weeds are grouped by growth form categories. Cover values were estimated in 10 x 10 m plots for perennials and 1 x 1 m subplots for annuals. Reference areas were also unsprayed but had very low initial weed cover.

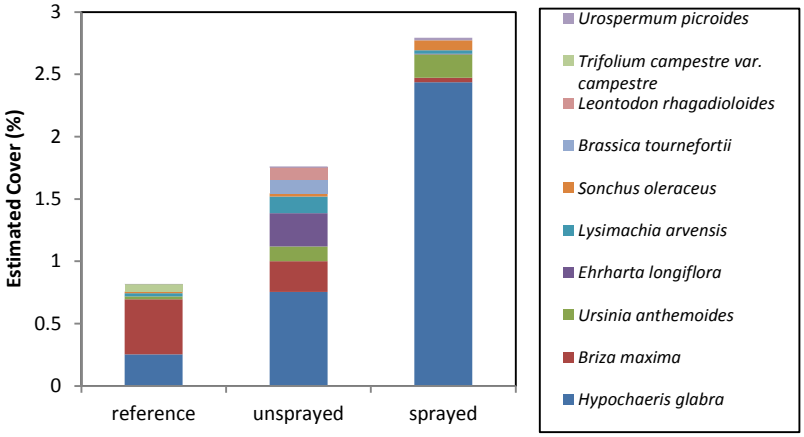

Figure 23. Cover of the top 10 annual weeds in monitoring sites in 2015, after two years of veldt grass spraying. Annual weeds such as *Hypochaeris* and *Ursinia* initially became more dominant after spraying greatly reduced the cover of perennial veldt grass (*Ehrharta calycina*). These are estimates of cover in five 1 x 1 m plots within each 10 x 10 m quadrat.

8. Monitoring the Recovery of Banksia woodland after Fire

A very severe bushfire in Banjup in February 2014 burnt all seven BWR monitoring plots in Shirley Balla Swamp within Jandakot Regional Park (Figs. 24, 25), but the remaining 24 weed management monitoring plots in other reserves were unaffected. The burnt plots were located in areas with high or low veldt grass cover and included plots that were sprayed in 2013 or remained unsprayed to assess weed management outcomes. These plots can no longer be compared to unburnt plots to monitor weed management, but have since been used to monitor changes in plant density, cover and diversity after fire. This monitoring occurred

monthly for the first six months and quarterly until November 2015, 21 months after the fire. The results are summarised briefly here:

1. The average mortality of trees resulting from the Shirley Balla fire was much higher for small trees with stem diameter less than 20 cm (Fig. 26). Banksias seem to require several decades of growth before they are large enough to become resilient to fire. Thus, frequent fires may decrease tree cover in banksia woodland.
2. There was a 39% total mortality of banksia trees, with many surviving trees resprouting from the trunk or base only, as shown in Fig. 27. Some resprouting trees later died. Large trees were more likely to resprout in the canopy and thus recover more rapidly than smaller trees.
3. There was spectacular banksia seed germination in the first winter after the fire, with over 13,000 banksia seedlings per ha, compared to about 600 per hectare before the fire (Fig. 28). About 20% of banksia seedlings that germinated in 2014 survived the summer of 2014/15 (these are called yearlings in Fig. 28). Banksia germination rates dropped back to values typical of unburnt sites nearby in 2015. There were many *Nuytsia floribunda* seedlings in one plot in 2015 (data not shown).
4. Plant cover, measured by visual estimation and photographic methodologies, is steadily increasing, reaching 40-70% of the pre-fire native cover by 19 months after the fire (Fig. 29).
5. Resprouting plants dominated initially, but those that recruited from seed became almost as diverse during the first winter after the fire (months four to seven in Fig. 30). Species that recover by resprouting from the base, stem, rhizome, tuber and roots are all represented after the fire.
6. Initially there were major benefits of weed control after the fire since perennial veldt grass cover was less than 5% in sprayed areas in 2014 but veldt grass cover became more substantial in some areas which were not sprayed again in 2015 (Fig 20E).
7. Floristic changes after the fire include a loss of eight native and one weed species from the plots, a gain of 16 native species (a number of these being short-lived fire-responsive species), and a gain of 27 weed species (Table 7).

Table 7. Floristic changes in plots at Shirley Balla resulting from the February 2014 fire.

Before the fire (2013)		**Over the 19 months after the fire (2015)**	
Native species	**Weed species**	**Native species**	**Weed species**
114	13	121	39
8 native species were only recorded **before** the fire:	1 weed species was only recorded **before** the fire:	16 native species were **new** after the fire:	27 weedy species were **new** after the fire:
Allocasuarina fraseriana, Daucus glochidiatus, Microlaena stipoides, Microtis media, Millotia tenuifolia, Pelargonium littorale, Sowerbaea laxiflora, Thysanotus sparteus	*Disa bracteata*	*Aotus procumbens, Calandrinia* sp., *Cartonema philydroides, Eucalyptus rudis, Hemiandra pungens, Ixiolaena viscosa, Jacksonia furcellata, Kennedia prostrata, Lachnagrostis filiformis, Macarthuria apetala, Menkea australis, Phlebocarya filifolia, Podotheca gnaphalioides, Quinetia urvillei, Senecio diaschides/glomeratus, Senecio pinnatifolius* var. *latilobus*	*Acetosella vulgaris, Aira caryophyllea / cupaniana* group, *Aira praecox, Arctotheca calendula, Briza minor, Carpobrotus edulis, Cirsium vulgare, Cotula coronopifolia, Echium plantagineum,* weedy *Eucalyptus* spp., *Galium murale, Gamochaeta pensylvanica, Lactuca serriola, Lagurus ovatus, Lotus subbiflorus, Lysimachia arvensis, Petrorhagia dubia, Phytolacca octandra, Poa annua, Polycarpon tetraphyllum, Rostraria cristata, Sagina procumbens, Solanum nigrum, Symphyotrichum squamatum, Trifolium* sp., *Urospermum picroides*

These results suggest that a mosaic of different fire ages should help to maintain high species richness in banksia woodland. However, fire-responsive plants that grow from seed stored in topsoil require sufficient time between fires to set seeds to replenish the soil seed bank. Plants that resprout after fire also require time to rebuild their canopy and replenish depleted reserves. More research is required to understand how long it takes individual species to recover after a fire. A key initial finding of this study is that fire substantially promoted the diversity and relative dominance of weeds, especially without veldt grass control.

Figure 24. Recovery of *Banksia attenuata* trees and accompanying vegetation in a 10 x 10 m plot at Shirley Balla Swamp from 2013 to 2015.

Row 1 left. Before the fire, showing high veldt grass cover.

Row 1 right. The first signs of resprouting on the banksias, six weeks after the fire.

Row 2 left. Banksias continue to resprout, geophytes have re-emerged and annual seedlings have germinated by June, four months after the fire.

Row 2 right. Native grasses are seeding, and *Nuytsia floribunda* and *Haemodorum spicatum* are flowering by November, nine months after the fire.

Row 3 left. The banksias have grown substantially over the summer, pictured here in February, 12 months after the fire.

Row 3 right. Native and weedy resprouted perennials (including perennial veldt grass) are filling in the understory, pictured here in September, 19 months after the fire.

Figure 25 Time series photographs which illustrate the recovery of common banksia woodland plants in the first two years after fire at Shirley Balla Swamp (February 2014 to November 2015).

Row 1 - *Eucalyptus todtiana,* a tree resprouting mainly from the canopy.

Row 2 - *Macrozamia fraserii*, a cycad which resprouts vigorously and rapidly from the base.

Row 3 - *Nuytsia floribunda*, the WA Christmas tree, resprouting from the base. This tree can also resprout vigorously from the trunk and from roots. This specimen flowered in the second spring after the fire.

Row 4 - *Xanthorrhoea* sp.*,* a grasstree, resprouting from the base. The foreground plant was very severely impacted but still eventually recovered. The background *Xanthorrhoea* specimen flowered in the first spring after the fire.

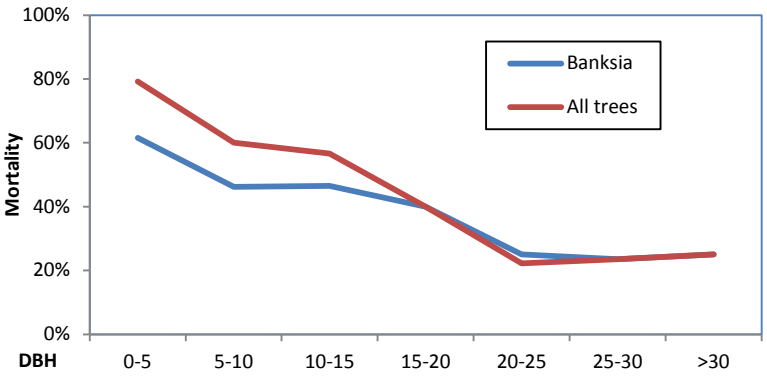

Figure 26. The relationship between tree size and total mortality at Shirley Balla Swamp, due to the February 2014 fire. Large banksia trees were more resilient than smaller banksias or small trees such as *Kunzea glabrescens*. Data are from four 25 x 25 m plots and the size classes are diameter at breast height in cm (DBH).

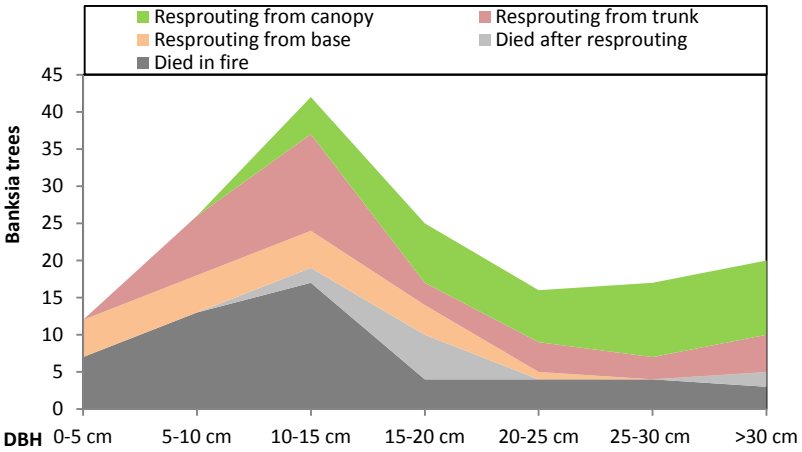

Figure 27. Recovery of *Banksia attenuata*, *B. menziesii* and *B. illicifolia* trees after the February 2014 fire at Shirley Balla Swamp, measured in 2015. Mortality was lower for trees over 20 cm in diameter. Overall, 33% of banksia trees were killed initially, 6% died after resprouting, 25% resprouted from the canopy, 23% resprouted from the trunk and 13% resprouted from the base only (see Fig. 26 for more information).

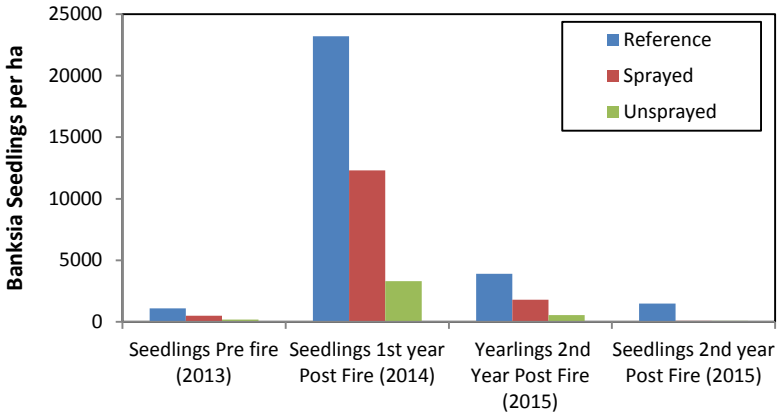

Figure 28. Banksia seedling germination at Shirley Balla Swamp before and during the two years following fire. The survival of banksia yearlings (one year old seedlings from 2014) in spring 2015 is also shown. Seedlings are primarily *Banksia attenuata* and *B. menziesii*. These are average counts from 10 x 10 m plots.

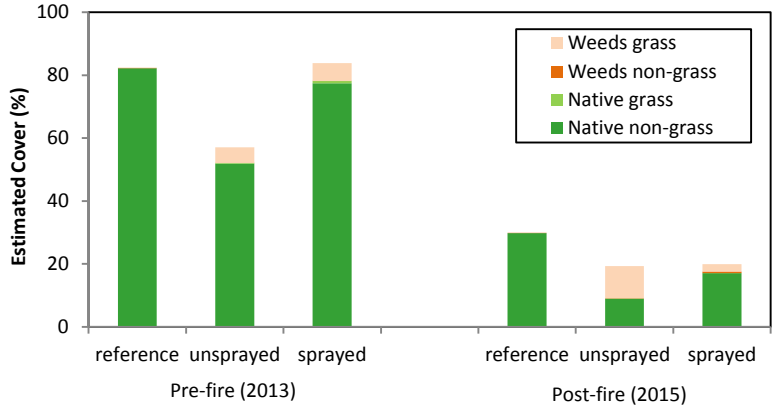

Figure 29. The cover of perennial natives and weeds before and after the fire in Shirley Balla Swamp in areas with or without spraying of herbicides to manage grassy weeds. Data are the average cover of all species in each category from 10 x 10 m plots. Weedy grass cover (mostly veldt grass) increased in unsprayed areas after the fire, but not in sprayed or reference areas. Reference areas were also unsprayed but had very low initial weed cover.

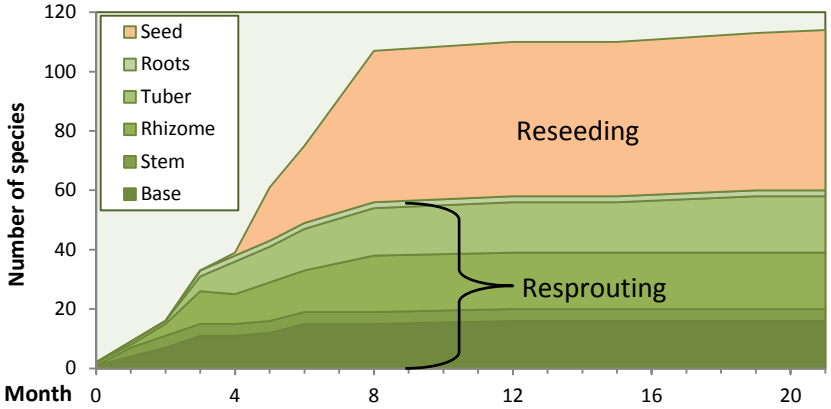

Figure 30. Changes in the relative importance of native plants differing in regeneration strategies over 21 months after the fire. This graph shows the species richness of plants that germinated from seeds, or resprouted from roots, tubers, rhizomes, stems and bases. There were 50 reseeding and 60 resprouting species in total within seven 10 x 10 m monitoring plots.

9. Monitoring Fauna in Restoration and Weed Management Sites

A fauna monitoring program occurred from 2012 to 2014 with the aim of recording key species such as Carnaby's cockatoos and southern brown bandicoots (*Isoodon obesulus*), as well as terrestrial vertebrates. This monitoring occurred at six sites to investigate whether weed management improved the quality of existing habitat and whether restoration created new fauna habitat. Southern brown bandicoots and Carnaby's cockatoos were only noted in the reference sites, whereas macropods were present at all sites. The number of ant functional groups increased over two years in the restoration sites. 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. Pollination of native plants was observed at all sites. Lastly, Rapid Bushland Assessments are being undertaken in both restoration and some perennial veldt grass management sites as part of a larger monitoring program across metropolitan habitats. This work is now concluded and summarised in a report (Moore and Barrett 2013).

10. The Banksia Woodland Community Restoration Grants

In 2014 a new grants program administered by the Department of Parks and Wildlife was initiated to help support community groups to manage and conserve banksia woodland (Fig. 31). Using funding from the Jandakot Airport offset, these grants fund community restoration projects from June 2014 to October 2016. Twenty projects were successful from a pool of 35 applicants resulting in 16 groups working at 21 locations, as shown in Fig 21B. Grants ranged from $5000 to $20,000 with a total value of $303,000 (ex GST). There are 11 projects to restore banksia woodland habitats through revegetation, four to manage weeds and five for *Phytophthora* dieback management, as listed in Table 8. The BWR project also provided seed of banksia woodland plants to the Waterbird Conservation Group for restoration projects at Canning River Regional Park and Maramanup Pool. Records of group contributions of cash and in-kind support and hectares restored have been included in Table 8.

Groups were asked to submit an interim report by October 2015. Four projects have been completed, three of which were phosphite applications to manage *Phytophthora* dieback and the other was a woody weed management program. Sixteen projects are ongoing (Fig 32). The grant program allows 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 from schedules ranged from a decreased capacity, lack of available seed, actual expenses less than original budget or extra in-kind contributions by partner organisations.

Table 8. Recipients of Banksia Woodland Community Restoration Grants.

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.)	$18,000	> 200 hours and plants	3
Birdlife Western Australia (BGPA, Friends of Bold Park)	Revegetating the Eastern Gateway for Carnaby's (planting, monitoring, etc.)	$20,000	Hours[1] and $2,500	0.4
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	470 hours and $37,153	22
Friends of Ken Hurst Park (City of Melville, Green Army, SMRC)	Restoration of degraded areas in Ken Hurst Park	$12,275	220 hours, plants and $300	0.1
Friends of Maida Vale Reserve (City of Kalamunda, EMRC)	The Friends of Maida Vale: Banksia Woodland TEC Restoration Project	$12,800	256 hours and $104	2
Friends of Queens Park Bushland (City of Canning)	Maniana Reserve Revegetation Project	$9,981	Hours[1] and materials	0.2
The Friends of Shenton Bushland, Inc. (City of Nedlands)	Restoring "The Barrens" as Cockatoo Habitat	$20,000	89 hours and $12,500	2
The Friends of the Spectacles (Kwinana Community Share)	The Friends of the Spectacles - Banksia Woodland Revegetation Areas	$20,000	458 hours and plants	2
Greening Australia (Landowner, Alcoa, community group)	Peel Biolinks - Connecting Landscapes for the Future	$20,000	Hours[1]	9
The Kingsley Montessori School	Montessori Weed Control	$5,060	600 hours	1
Landcare Serpentine Jarrahdale, Inc. (Landowner)	Thompson's Dieback Treatment Project	$8,655	18 hours	45
Landcare Serpentine Jarrahdale, Inc. (Landowner, Dieback Treatment Services)	Elliot Banksia Woodland Dieback Treatment	$20,000	$3,818	95
Landcare Serpentine Jarrahdale, Inc. (Landowner, Healthy Wetland Habitats – Parks and Wildlife)	Banksia Ridge : Removal of Eucalyptus camaldulensis at Rapids Road	$13,100	200 hours and $3,400	13
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	220 hours	8
North Swan Land Conservation District Committee (WAPC)	Weed Control and Dieback *Phytophthora* management of Banksia Woodland in West Bullsbrook	$14,955		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[1]	0.8
Waterbird Conservation Group, Inc.	Banksia Woodland Restoration on a sandy rise adjacent to Maramanup Pool, Baldivis	$20,000	>587 hours and $8144	0.7
Total		$302,697		1,041

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

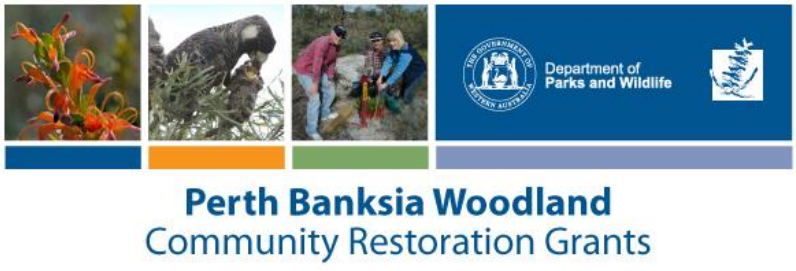

Figure 31. Logo for the community grants programme.

Figure 32. Examples of activities funded by the Banksia Woodland Community Restoration Grants program **A.** Direct seeding at a Peel Biolinks site. **B.** Community planting day at a Peel Biolinks site, July 2015. **C.** Planting with Japanese exchange students at Baldivis Children's Forest. **D.** Grab-a-Gladdie event at Maida Vale Reserve.

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. Weed management at Wandi Nature Reserve has now concluded successfully, but spraying at Fraser Road bushland was postponed until 2016 due to site access problems caused by development of adjacent areas. The BWR project is also providing support for translocation of *Caladenia huegelii* into Jandakot Regional Park using offset funding from a development at Wandi. This funding will be used for seed baiting trials to identify translocation sites, as well as fencing and weed control in these areas. The BWR project also supports the Friends of Ken Hurst Park for restoration work in habitats for *Caladenia huegelii*.

12. Dieback Research Projects

Banksia species are extremely susceptible to the introduced soil borne pathogen *Phytophthora cinnamomi*. However, some banksias survive and seedlings establish after the majority of banksias have died on infested sites. A preliminary project by Dr Elaine Davison at Curtin University, funded by the BWR, investigated whether these survivors are disease escapes or resistant by measuring the radial extent of sapwood invasion following inoculation of the pathogen in the laboratory. Potential resistance was tested using excised branches from three *B. menziesii* and nine *B. attenuata,* three of which were tested twice, from two infested sites (Hakea Prison and Anketell Road). Results show that *P. cinnamomi* 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 (all trees were tagged and geo-referenced). The BWR project has also collected samples of seed at four locations from possibly

resistant trees, including those from which branches were tested, so they can be used for seedling resistance screening.

13. Project Management and Governance

For most of 2015 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 9 and meetings were held every six to 12 months from 2011 to 2014. This committee did not meet in 2015, but a workshop is planned in 2016. 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 10.

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 9. 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
Dr. Mark Brundrett	Senior Ecologist BWR Project, Swan Region

Table 10. BWR Project objectives and outcomes to December 2015.

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 works 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 with Neal Enright and Joe Fontaine 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	15,000 seedlings grown and planted in 2015
12. Direct seeding and planting native plants	Investigate effectiveness of direct seeding and planting for banksia woodland establishment	Most planting and seeding concluded in 2015, but seeding is required 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	Spraying of reserves for weed control was not possible in 2015 due to funding delays
15. Controlling illegal site access	Fencing to protect banksia woodland from disturbance, weeds and *Phytophthora* dieback	Fencing works to protect banksia woodland in reserves mostly completed
III. Collaborations		
16. Community Group and Local Government	Manage high priority sites with community groups and local government (e.g. Friends of Ken Hurst Park)	Planting by volunteers July 2015. 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*	Works to improve *Caladenia huegelii* habitats commenced. Staff attended rare flora surveys in 2015
19. Scientific research program	Research to measure and optimize plant and animal diversity in restoration sites	Funding provided to support 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 Collaboration in 2015

A. Presentations

Talks for community groups and scientific conferences by Mark Brundrett in 2015 are summarised below. Most of these are about the BWR project, but several talks and workshops concern orchid conservation.

1. Presentations to community groups such as the Wildflower Society – February 10, October 13, September 23, and November 19.
2. Site visits with community groups and stakeholders - May 26, May 27, and April 10.
3. Presentation for Jandakot Community Consultative Committee - September 10.
4. Site visit for Jandakot Community Advisory Committee - July 14.
5. Project update for Swan Region natural area management team (10 presentations) – 24th March 2015.

B. Publications and Publicity

Publications and reports in 2015 that are listed in Appendix 1 include:

1. Article on banksia woodland fire recovery for the Wildflower Society of Western Australia.
2. Interactive website for banksia woodland plant identification and another on pollination.
3. An article for Land for Wildlife has been submitted.

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 provided volunteers to plant and water tubestock and monitor restoration areas in 2015.
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. Friends of Upper Lesmurdie Falls received flora advice for their restoration project in the Mundy Regional Park, above Lesmurdie Falls.
7. Regional Parks received flora and monitoring advice on the Roe Highway Extension project.
8. Regional Parks received flora and restoration/revegetation advice on the Eglinton Estates offset.
9. Advice and seed provided to support the Department of Parks and Wildlife-managed Dundas Road and Lowlands Restoration projects.

15. References (see Appendix 1 for Reports)

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Appendix 1. Publications and Major Reports

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

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

Appendix 2. Native Plant Species Present in Restoration Areas

Plants present in revegetated sites the fourth year after establishment (2015). 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 2012 -2015	Local Opportunist	Dampland only	First flowering
Acacia huegelii	1			1			2014
Acacia pulchella	1			1			2014
Acacia saligna	1			1			
Acacia stenoptera	1						2015
Adenanthos cygnorum	1						2015
Allocasuarina fraseriana			1	1			
Allocasuarina humilis			1	1			
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			
Banksia ilicifolia			1	1			
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 pomiformis	1				1		
Centrolepis drummondiana	1						2012
Centrolepis inconspicua	1						2013
Chamaescilla corymbosa	1						2013
Comesperma calymega	1						2013
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 (2 subsp.)	1						2012
Croninia kingiana	1						2014
Dampiera linearis	1			1			2013
Dasypogon bromeliifolius	1	1	1	1			2013
Daucus glochidiatus	1						2014
Daviesia nudiflora	1						
Daviesia physodes	1						
Desmocladus asper?	1			1			
Desmocladus flexuosus	1			1			
Dianella revoluta				1			
Dichopogon capillipes				1			
Diuris corymbosa	1						2014
Drosera erythrorhiza	1						

Species	Topsoil	Topsoil and other	Direct Seeded	Planted 2012 -2015	Local Opportunist	Dampland only	First flowering
Drosera glanduligera	1						2012
Drosera macrantha	1						2013
Drosera paleacea	1						
Epilobium hirtigerum					1		2013
Eremaea asterocarpa			1	1			2013
Eremaea pauciflora	1		1	1			2015
Eucalyptus marginata			1	1			
Eucalyptus rudis				1	1	1	
Eucalyptus todtiana			1	1			
Exocarpos sparteus					1		
Gastrolobium capitatum	1	1	1				2014
Gnephosis angianthoides	1						2012
Gompholobium tomentosum	1	1	1	1			2013
Gonocarpus pithyoides	1						2013
Grevillea vestita	1						
Haemodorum spicatum	1	1	1				2013
Hakea prostrata			1				
Hardenbergia comptoniana	1				1		
Hemiandra pungens	1			1	1		2013
Hensmania turbinata	1						2014
Hibbertia huegelii	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
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 riedlei			1				
Melaleuca preissiana				1		1	
Melaleuca rhaphiophylla				1		1	
Melaleuca seriata			1	1			2013

Species	Topsoil	Topsoil and other	Direct Seeded	Planted 2012 -2015	Local Opportunist	Dampland only	First flowering
Melaleuca teretifolia				1		1	
Melaleuca thymoides	1	1	1	1			
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						
Petrophile linearis			1	1			2015
Philotheca spicata	1						
Phlebocarya ciliata	1			1			
Phlebocarya filifolia				1			
Phyllangium paradoxum	1						2012
Phyllanthus calycinus	1						2013
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	
Regelia inops				1			2015
Rhodanthe citrina	1						2012
Scaevola repens	1						2015
Schoenus curvifolius	1			1			2014
Schoenus efoliatus	1			1			
Scholtzia involucrata	1		1	1			2014
Senecio pinnatifolius					1		2013
Siloxerus humifusus	1				1		2012
Sowerbaea laxiflora	1						
Stachystemon?	1						
Stirlingia latifolia	1	1	1	1			2015
Stylidium brunonianum SL (S. araeophyllum MS)	1						2013
Stylidium piliferum	1						2013
Stylidium repens	1						2015
Synaphea spinulosa	1						
Thysanotus arbuscula	1						2012
Thysanotus manglesianus (sp. Climbing)	1						2015
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	**114**	**15**	**36**	**69**	**22**		

Appendix 3. Cost Estimates for Banksia Woodland Restoration

A. Cost per hectare comparisons of different methods to establish native plants

Restoration Method	Annual $ / ha highest	Annual $ / ha lowest	Cost / ha seed only*	TOTAL COST / ha ($ over 4 years)	Main reasons for cost variations	Outcomes
Direct seeding	13,000	8,000	4,286	12,000	Fencing, size of area, weed control ($8000 / ha without fencing)	Variable seed germination and summer drought losses – planting also required
Nursery tubestock	3,300	1,500	1,050	15,000	Seed quality, container size, planting costs ($10,000 / ha excluding cost of planting)	Variable losses due to summer drought - 4 years of planting was required
Topsoil transfer	other quotes higher	17,000	0	17,000	Availability of weed and dieback free soil, transport distance	Variable due to soil quality, weeds and summer drought - planting or seeding is also required

B. Cost per plant comparisons of different methods to establish native plants

Restoration Method	Cost / plant highest $	Cost / plant lowest $	Cost of seed only $[6]	Density in 2014 (stems/ha)	Main reasons for cost variations	Outcomes
Direct seeding	10.00	5.00	1.00	800 - 1,100	Fencing, weed control, scale of operations and summer losses	Preliminary results only
Nursery tubestock	4.44	2.62	1.00	600 - 800	Variations in seedling germination and seed cost. Higher cost includes clonally propagated plants.	Four years of planting required[5]
Topsoil transfer - large plants only[1]	6.98	2.02	0	2,700 - 4,200	Costs are from before and after severe summer drought losses in 2013/14	Topsoil provided most of the plant diversity, but not the trees
Topsoil transfer - all perennials	0.70	0.50	0	24,000 - 31,000	Includes seedlings and plants < 1 year old that may not survive	New seedlings emerge each year, but many do not survive
Topsoil transfer - annuals only	0.10	0.03	0	>500,000	Annual natives thrive in restoration sites, but are patchy	Expected to decline in importance as cover develops

Notes: 1 Large plants are more than one year old. 2 Effective restoration often requires both seeding and tubestock (and topsoil if available). 3 It usually takes three to four years of planting to reach targets and replace summer losses. 4 Costs are for 10 - 30 ha (scale dependant). 5 Planting densities were set to reach 400 trees per hectare and 7000 understory plants per hectare. 6 Seed cost is also included in previous columns. 7 No monitoring, management, or reporting costs are included. 8 Total costs per hectare are not additive as areas with direct seeding or topsoil required less tubestock.