Banksia Woodland Restoration Project

Annual Report 3

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Department of Parks and Wildlife

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Abbreviations

- Australian Department of the Environment (Canberra) formerly the Department of Sustainability, Environment, Water, Population and Communities (SEWPAC)
- DEC – West Australian Department of Environment and Conservation (now Parks and Wildlife)
- Department of Parks and Wildlife (formerly part of DEC)
- BWR - Banksia Woodland Restoration Project (this project)
- JAH – Jandakot Airport Holdings Pty Ltd
- TFSC - Threatened Flora Seed Centre (Parks and Wildlife, Kensington)
- CBC - Carnaby's cockatoo, Carnaby's black cockatoo (*Calyptorhynchus latirostris*)
- TEC – Threatened Ecological Community
- Restoration – Ecosystem Restoration is the "process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (SER Primer, 2004). In this report it more specifically concerns establishing a particular type of native vegetation where it is absent.
- Rehabilitation – has a similar general meaning to restoration, but in this report refers more specifically to other actions such as weed management to promote recovery of existing but degraded native vegetation.
- Completion Criteria – numeric targets or milestones for restoration projects used to report outcomes.

Executive Summary

The Banksia Woodland Restoration (BWR) Project is managed by the Western Australian Department of Parks and Wildlife to undertake restoration work. It is funded by Jandakot Airport Holdings Pty Ltd (JAH) as part of the Commonwealth requirement to offset the impacts of clearing 167 ha of native vegetation at Jandakot Airport in Western Australia. This Department of the Environment (formerly SEWPAC) offset requires JAH to provide Parks and Wildlife (formerly DEC) with $9,200,000. The role of Parks and Wildlife is to use these funds for rehabilitation and conservation activities for banksia woodland within 45 km of the airport. Jandakot Airport Holdings subsequently negotiated changes to EPBC Act conditions in 2014 that have delayed payment of 40% of the offset funds, possibly for several years. The final payments are now expected in 2016 and 2017, but uncertainty about this has significant operational implications for the continuation of the BWR project in its current form. 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 management using a ranking process based on environmental values, especially concerning habitats for Carnaby's cockatoos (*Calyptorhynchus latirostris*) and the grand spider orchid (*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 for assessing banksia woodland biodiversity and condition.
7. Support community groups who help to manage banksia woodlands.
8. Collate and share information on banksia woodland biodiversity and condition.

In September 2011, the Banksia Woodland Restoration project (BWR) initiated large-scale restoration and rehabilitation works on the Swan Coastal Plain in the Perth Metropolitan Region conservation estate. Works undertaken or underway for the BWR project in the first 3 years include:

1. Site ranking and selection of restoration sites, giving highest priority to banksia woodland habitats most similar to those at Jandakot Airport, with high conservation values, habitat for Carnaby's cockatoos and areas where the grand spider orchid occurs.
2. Establishment of 16 ha of new banksia woodland in cleared areas using topsoil from Jandakot Airport, as well as direct seeding and planting seedlings over 40 ha in total.
3. Banksia woodland rehabilitation to protect and substantially increase areas in very good condition at locations shown in the map below by:
    a. Weed management of over 600 ha of bushland to control the most serious environmental weeds.
    b. Fencing up to 25 km of reserve boundaries to reduce illegal access and disturbance with associated rubbish dumping, weed and phytophthora dieback spread.
    c. Infill planting of banksia trees in areas where existing native canopy cover is sparse due to disturbance (about 10 ha).
4. Establishing a network of banksia woodland biodiversity and condition monitoring sites.
5. Providing support to community groups and local governments to restore banksia woodland at 20 locations.

The main aim of restoration work is to establish vegetation that is self-sustaining with minimal management in the future. Restored vegetation also must comprise of local provenance native plants established at appropriate target densities set using reference site data. Restoration reference sites were established at Jandakot Airport (where the topsoil was sourced) as well as areas adjacent to restoration sites. Flora surveys of these areas 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.

Sites for restoration of banksia woodland in completely degraded areas dominated by weeds were selected at Forrestdale Lake and Anketell Road Bushland in Jandakot Regional Park, with a total area of over 50 ha (see Table below). Restoration of these sites was initiated by topsoil transfer in April-May 2012 and by

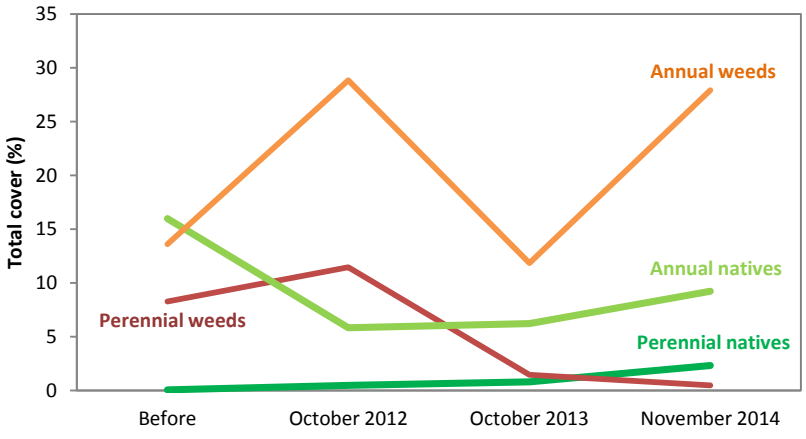
planting nursery-raised seedlings and direct seeding from 2012 onwards (see Table below). In total 18,000 nursery-raised native plants were planted in 2014. This allowed completion targets for banksia trees and other trees and shrubs to be reached, but it is anticipated that more planting will be required in 2015 to replace summer losses. Direct seeding conducted in collaboration with Greening Australia (WA) continued in 2014 to increase the area restored by 12 ha.

The BWR project utilises the Parks and Wildlife Threatened Flora Seed Centre to manage seed collection, and for seed research to resolve problems with the nursery production of some species. A major seed collection for banksia woodland restoration has now been established as a key resource for this and other restoration projects. In 2014, 474 seed batches for 122 species were received, 143 tested for germination, 102 batches supplied to nurseries and 155 used for direct seeding (28 kg). Seed collected for the BWR project was also supplied to community groups and for other restoration projects. Seed collection locations are shown in the map below.

Recruitment from topsoil has been impressive with over 100 species of native plants arising from this source, but their distribution was patchy, resulting in some poor areas where additional planting was required. In total, there are over 150 species of native plants in the restoration sites, including those introduced by planting and direct seeding. This is similar to plant diversity at the reference sites. Perennial native plant cover is still much lower than in reference sites, but increases gradually each year (see graph below). Annual native plants and weeds were initially dominant in restoration areas, but perennial weed cover has decreased substantially following weed control actions (see graph). Work to reach completion targets for the density and diversity of trees and understory plants is expected to conclude after another year, but weed control and monitoring will need to continue for longer. Native plant growth from topsoil peaked at over 700,000 stems per ha in 2013, then declined substantially following an extremely hot and dry summer in 2013/2014, but was still sufficient to meet targets prior to the summer of 2014/2015. The cover of perennial native plants is slowly but steadily increasing, as shown in the graph below. A key outcome of this monitoring will be to determine the relative effectiveness and cost of different methods for restoration and the overall costs and resources needed for banksia woodland restoration.

Banksia Woodland Restoration Actions by Area (areas overlap)

Restoration activity	Timing	Anketell Rd (ha)	Forrestdale Lake (ha)	Total (ha)
Topsoil transfer	2012	11.5	4.5	16
Planting	2012-2014	32	7.5	39.5
Direct seeding	2012-2014	27	0.5	27.5
Total restoration area		**39**	**11**	**50**

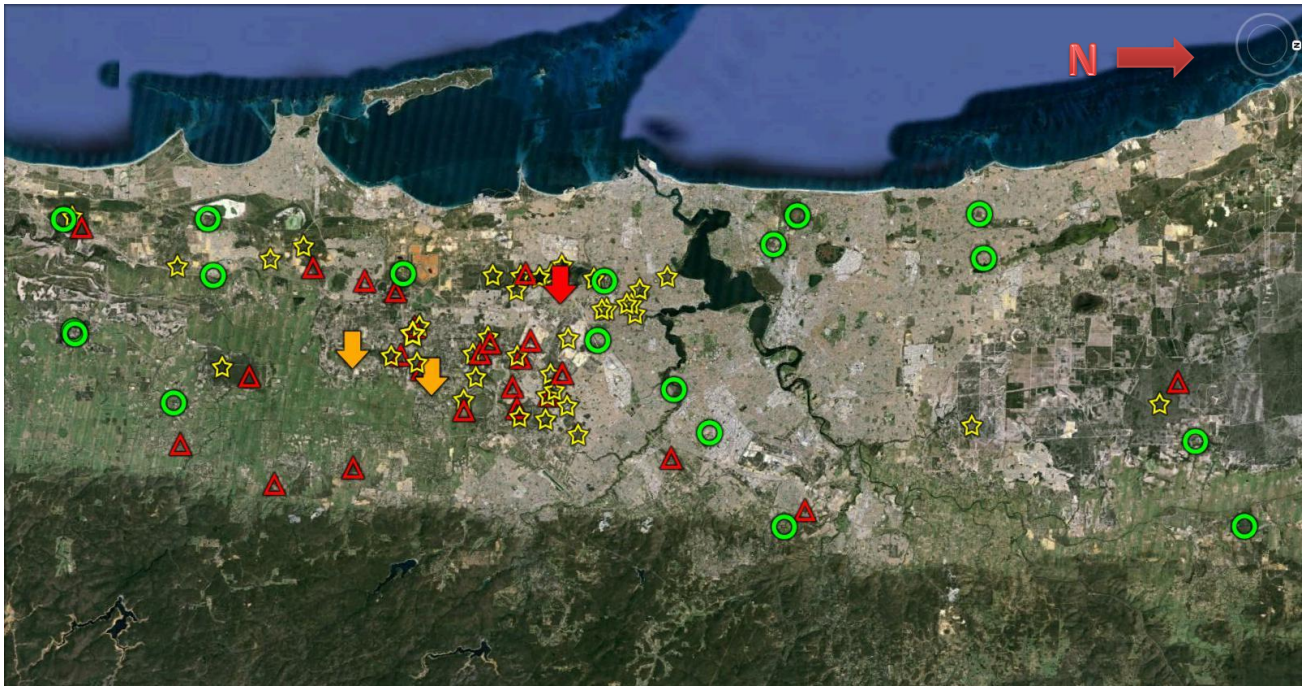


Vegetation cover trends over the first 3 years in the largest restoration site, Anketell Road. The cover of perennial native plants is gradually increasing due to seedling germination from topsoil and planting. The reduction in perennial weeds is due to herbicide spraying. The number of perennial native plants from topsoil is very high (up to 700,000 stems per ha) but their contribution to cover is still low after 3 years.

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. Following a comprehensive weed

mapping program, a prioritisation process covering 1400 ha was used to select sites for a major weed control project that commenced in 2013 and continued in 2014. In 20 locations, over 320 ha of perennial veldt grass (*Ehrharta calycina*) control was undertaken using grass selective herbicides in 2013. Most of these sites were also sprayed again in 2014 to ensure effective control of grasses. Seven other species of major environmental weeds were also targeted in these areas. The BWR project has also funded major weed management, fencing and planting in 10 of the most important natural areas on the Swan Coastal Plain. These projects were managed by Parks and Wildlife's Swan Coastal District and the Urban Nature Program. In total, weed management projects extend over 600 ha in 23 reserves. The BWR project will continue weed control actions for another year to ensure successful outcomes have been met. In 2014, offsets funding was used to run a community grants program where the BWR project also provided $300,000 in funding to 17 community groups for restoration work, weed management or dieback control at 20 locations, as shown in the map below.

Comprehensive monitoring programs were established in 2013 to measure changes to banksia woodland plant diversity and vegetation condition following effective perennial veldt grass control by spraying a selective herbicide. This monitoring, which occurs at in 31 plots at five locations, measures plant abundance and cover and also utilises reference photographs and aerial photography. Weed control primarily increased the relative dominance of annual plants over the first 2 years, so several more years of monitoring is required to measure the response of perennial native plants. A very severe wildfire in Banjup burnt 7 of these monitoring plots in Shirley Balla Swamp in February 2014. Since then, we have taken monthly measurements of plant density, cover, and diversity in the burnt area. These data revealed a 23% mortality rate for trees, very high banksia seed germination (4,000-11,000 per ha) and also showed that more plant species recovered by seed germination than by resprouting, but the latter resulted in more cover. This work also demonstrated benefits of weed control before the fire, since perennial veldt grass cover was under 1% in sprayed areas, but was over 5 % in unsprayed areas in the first year following fire. Fauna monitoring commenced in 2013 in the two restoration areas and banksia woodland reference sites to investigate fauna diversity and abundance in these areas. There were few native mammals but substantial numbers of birds, reptiles and amphibians were detected in all the areas surveyed.



Banksia Woodland Restoration (BWR) project locations in the Perth Metropolitan Region relative to Jandakot Airport (red arrow). These include two major restoration areas (orange arrows), sites for weed management and fencing (red triangles), seed collections (yellow stars) and funding provided to community groups (green circles).

Table of Contents

1. Introduction and Background

The Jandakot Airport Offset Plan was developed in 2010 by Jandakot Airport Holdings Pty Ltd (JAH) as an offset for the clearing of up to 167 ha of native vegetation at Jandakot Airport in Western Australia. The approval for this expansion of Jandakot Airport was subject to a number of conditions, specified in the EPBC 2009/4796 approval document (Government of Australia 2010). The conditions of the approval need to be fulfilled to the satisfaction of the Commonwealth Department of the Environment (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. Jandakot Airport Holdings subsequently negotiated changes to EPBC Act conditions in 2014 that have delayed payment of 40% of the offset funds, possibly for several years. The final payments are now expected in 2016 and 2017, but uncertainty about this has significant operational implications for the continuation of the BWR project in its current form.

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.

2. Seed Management and Storage

Banksia woodland restoration is very challenging because some key species fail to recruit from topsoil, so must be introduced by planting of nursery grown tubestock or direct seeding. However, growing plants from seed is also very difficult for many species due to problems with seed availability, quality or germination. Seed collecting is a major expense in all restoration projects and seed quality assessment is required to ensure this activity is being undertaken efficiently.

The BWR Swan Coastal Plain seed collection is stored in the Parks and Wildlife Threatened Flora Seed Centre (TFSC) and contains large amounts of seed from Jandakot Airport and from 35 other areas over a wide range of the Swan Coastal Plain, as well as small collections resulting from other offsets (Fig. 1). There are over 120 plant species in the collection with multiple provenances for the most important species. After 3 years of collecting, there are over 700 seed batches, including over 50 large batches of tree seed (some over 1 kg) available for use. These collections are stored in a temperature and humidity controlled environment for long term viability to supply the BWR project, and other restoration projects (Table 1). Further details seed collections and research are available in a separate report (Dudley et al. 2014).

Work by the TFSC has focussed on processing and testing seed batches from commercial seed collectors to send to the nursery, especially for species with low germination due to poor quality seed. This work focussed on tree seed, especially banksias, which are most expensive to collect due to the brief window of opportunity in early summer. Species which are common in banksia woodland but known to be difficult to collect or germinate were treated or pre-germinated in the laboratory before use in the nursery. Collections for 32 difficult species were also made by our staff (Fig. 2). In total, 546 seed collections were processed and quantified. In total 143 seed collections were tested for germinability in 2014 (Table 1).

In late 2013, about 2.4 kg of seed material comprising 257 collections and 63 species was sent to three nurseries (Table 1), resulting in about 18,000 plants for planting in 2014 (Table 2). Large seed batches were also prepared for direct seeding in 2014, with separate seed mixes for upland and lowland areas (142 batches for 54 species). Some species required pre-treatment prior to direct seeding. Banksia seed yield data was also used to help assess Carnaby's cockatoo food resources in banksia woodland.

Table 1: Seed batches processed, quantified and tested at the TFSC for the BWR project in 2013/2014.

	Number of Batches	Number of Species	Weight (kg)	Number of Seed or Fruit
Received	439	90		
Quantified	546	112		
Germinated	143	43		
Nursery Order	102	32	2.38	241197
Direct Seeding Orders	155	57	28	1458997
Seed Collections by our staff	35	32		

Figure 1. Seed collected from 40 locations in banksia woodland on the Swan Coastal Plain.

Figure 2. **A.** The Threatened Flora Seed Centre was used to manage over 700 seed collections and help diagnose and overcome problems with poor germination of some species (left).
B. Targeted seed collection occurred for 32 species where viable seed is difficult to source (right).

3. Production of Nursery Seedlings

Nursery seedling quality and hygiene specifications for disease control were rigorously defined in a panel tender, from which 4 nurseries were used in 2014. In 2014 about 20,000 seedlings were ordered from three nurseries and about 18,000 were received and planted (Table 2). There were substantially higher seed germination rates in the nursery compared to previous years, resulting from better seed management and quality control, as explained in Section 2. In total 7,952 tree seedlings including 6,250 banksia seedlings were planted (Table 2). In addition to nursery-raised seedlings, 2,817 plants of species that are difficult to propagate were produced by clonal division or specialised germination methods by a specialist nursery (Ben Croxford at the Nuts About Natives nursery). These species are indicated in the Table 2.

Seedlings planted in 2014 were grown in both standard nursery tubes (50 x 120 mm) and some banksias were grown in “super tubes” (67 x 160 mm) to provide a larger root volume at planting (Fig. 3). This allowed the role of container size on summer survival for banksias to be investigated.

For the first 2 years of restoration at Anketell Road and Forrestdale Lake (2012, 2013), nursery orders primarily consisted of trees and shrubs with canopy stored seed that was unlikely to regenerate from topsoil (see Table 2). In 2014, nursery orders were based on monitoring data from restoration sites and targeted species required for infill plantings to reach completion criteria targets. The number of each species required ultimately depends on the survival of tubestock planted each year, as well as recruitment from topsoil and direct seeding which is still continuing.

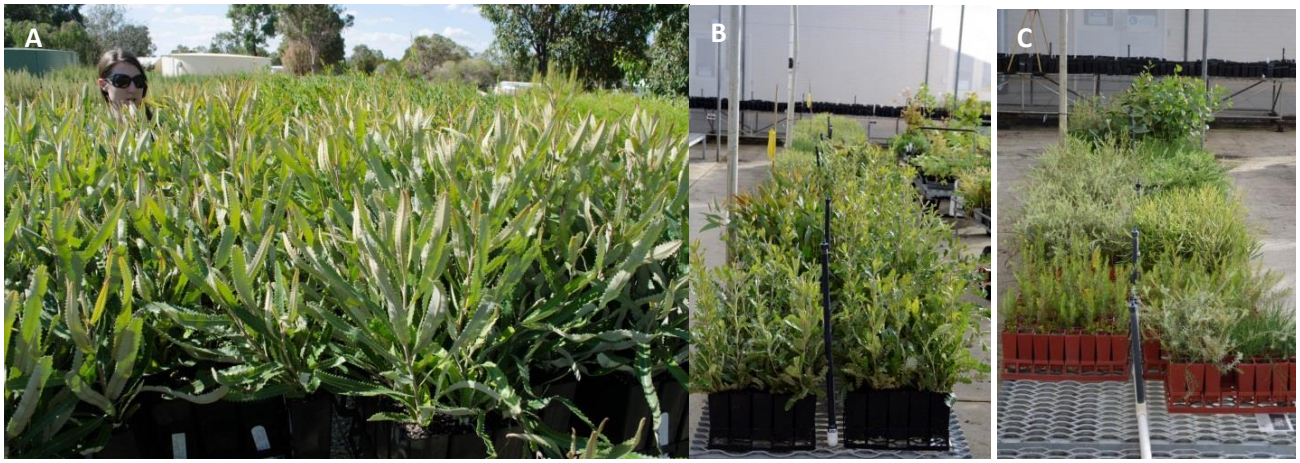


Figure 3. Examples of *Banksia menziesii* seedlings in a nursery (**A**) and seedlings ready for planting (**BC**). Some larger seedlings were grown in “supertubes” to investigate the role of plant size on survival (**A**).

Table 2. Nursery-raised seedlings planted in 2014.

Row Labels	Anketell Road	Forrestdale Lake	Pony Place	TOTAL
Acacia saligna	660	225	45	930
Allocasuarina fraseriana	47			47
Allocasuarina humilis	780	304	20	1104
Amphipogon turbinatus	46	22		68
Anigozanthos manglesii	308	130		438
Banksia attenuata	1746	1373	40	3159
Banksia ilicifolia	1076	260	60	1396
Banksia menziesii	1070	602	20	1692
Beaufortia elegans	135	65		200
Calothamnus lateralis	80	120		200
Calytrix fraseri	335	65		400
Conostylis aculeata	179	28		207
Corymbia calophylla	60	15	5	80
*Dampiera linearis**	30	10	32	72
*Dasypogon bromeliifolius**	136	21		157
*Desmocladus flexuosus**	120	14		134
Dichopogon capillipes	82	18		100
Eremaea asterocarpa	50	153	65	268
Eremaea pauciflora	53	66	20	139
Eucalyptus marginata	145	96	10	251
Eucalyptus rudis	141	115		256
Eucalyptus todtiana	274	120		394
Gompholobium tomentosum	176	68		244
*Hibbertia huegelii**	244	40		284
Hibbertia hypericoides	33	7		40
*Hibbertia subvaginata**	268	37	40	345
Jacksonia furcellata	66	60	10	136
Kennedia prostrata	75	40	5	120
Kunzea glabrescens	80	40		120
*Lechenaultia floribunda**	38	7		45
*Lepidosperma squamatum**	520	40	40	600
*Lyginia barbata/imberbis**	23	3		26
Melaleuca preissiana	270	124		394
Melaleuca rhaphiophylla	84			84
Melaleuca seriata	417	240		657
Melaleuca teretifolia		113		113
Melaleuca thymoides	540	269	5	814
Melaleuca viminea	40	40		80
Nuytsia floribunda	152	45	2	199
Orthrosanthus laxus	153	27		180
*Patersonia occidentalis**	532	40	40	612
*Phlebocarya ciliata**	182	37		219
Regelia ciliata	122	78		200
Regelia inops	16	7		23
*Schoenus curvifolius**	302	40		342
*Schoenus efoliatus**	36	7		43
*Scholtzia involucrata**	81		8	89
Stirlingia latifolia	65	16		81
Other spp. (14 spp.)*	68	9		77
GRAND TOTAL	**12,136**	**5,256**	**467**	**17,859**

*Propagated by a specialist nursery (clonal division or seed)

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	2,867	2,252	-	5,119
2013	8,287	4,425	175	12,712
2014	12,136	5,256	467	17,392
GRAND TOTAL	23,290	11,933	642	35,223

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 seed levels. These areas were then planted and small direct seeding trials were started in 2012 (Table 4). Larger planting and seeding programs occurred in 2013 and 2014, as explained below.

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. The upland and dampland areas were identified using historical aerial photographs and vegetation maps of adjacent areas. Topsoil from Jandakot airport was only applied to upland areas, as it contains species unsuited to dampland habitats.

In total, 18,000 nursery-raised native plants were planted in 2014 (Table 3). This allowed completion targets for banksia trees and other trees and shrubs to be reached, but it is anticipated that more planting will be required in 2015 to replace summer losses. Planting started in May 2014 and concluded in July. Tubestock was planted using an Ecojobs (Green Skills Inc.) crew of 4-5 people for 12 days and 3-5 of our staff for several weeks. Birdlife Australia volunteers planted trees on the 22nd June to provide crucial feeding habitat for Carnaby's cockatoo (Fig. 4). Most planting occurred within the fenced areas shown in Figures 5 and 6 Additional planting occurred around these areas to consolidate a larger area of banksia woodland. These were protected by tree guards. All seeded and planted species are listed in Appendix 2

In 2014, about 12 ha at Anketell Road were direct seeded for the BWR project by Greening Australia WA to establish some of the key species in banksia woodland, using seed drill technology to restore large areas efficiently (Fig. 6). Site preparation prior to direct seeding included weed control, scalping and ripping along seeding rows, as well as the application of fertiliser and wetting agent. To reduce grazing impacts in seeded areas, rabbit-proof fencing was installed around them (13 ha). The new fences were adjacent to areas fenced in 2012, giving a total protected area of 23 ha (Fig. 6).

Work to manage weeds in restoration sites is ongoing, with species ranked according to their invasiveness and competitive ability. Weed management initially focussed on control of perennial veldt grass (*Ehrharta calycina*) using a grass-selective herbicide and hand removal of the most invasive weeds (all bulbs, *Euphorbia, Pelargonium*, *Carpobrotus*, *Lupinus,* etc.). Spraying of couch grass and annual broad-leaved weeds also occurred in some parts of the restoration areas in 2014.

In 2014, a research trial was established to assess the best method of establishing banksia trees in restoration sites. Three pots sizes (cell-trays, standard forestry and super tubes) were used to grow banksias in the nursery in in 2014 to investigate the role of container volume. These seedlings were planted together in the same plots and direct seeded plants were also sown near them for comparison. Preliminary observations suggest banksias from larger tubes grow faster in the field (with more branching), but are more prone to sudden death (some have since resprouted). This trial utilised 24 (13 x 13 m) research plots at each site formerly used by Pawel Waryszak of Murdoch University for his PhD research.

JANDAKOT

Banksia woodland takes shape

CREATING NEW HABITAT FOR CARNABY'S COCKATOOS

VOLUNTEERS have teamed up with the State Government in a project to restore banksia woodland overrun by weeds and help attract native birds back to the Swan Coastal Plain.

The aim of the project, which is funded by Jandakot Airport Holdings to offset the clearing of 167 hectares of native vegetation at Jandakot Airport, is to improve habitat for wildflowers and native animals, including Carnaby's cockatoos.

In the first two years, weeds have been brought under control on 500 hectares in 20 conservation areas.

Work to establish 20 hectares of new banksia woodland is also taking place at Forrestdale Lake, east of Banjup, and in the Anketell Road area of Jandakot Regional Park.

A spokesman for the Department of Parks and Wildlife said the two locations were chosen because they are managed by the Department, contained soils suitable for the growth of woodlands and were within 45km of the airport.

"Planting is expected to conclude in 2015, while weed management will continue for several more years to allow native plants to grow and flourish in this area," he said.

"It is expected to take approximately 10 years to get substantial food supplies for Carnaby's cockatoos from the banksias that are currently being planted."

A

Mitch Borgogno,Mark Claxton and Daniel Jones from the Department of Parks and Wildlife, Jim Prince,David James and Bryony Fremlin from Friends of Forrestdale and Mark Brundrett from DPW. Picture: Martin Kennealey d422745

B

Figure 4. A. Community newspaper article about planting at Forrestdale Lake. **B**. BirdLife Australia volunteers planted native plants to restore habitat for Carnaby's cockatoos at the Anketell Road in June 2014.

A. Forrestdale Lake

Areas of Forrestdale Lake spread with topsoil transferred from Jandakot Airport, planted with tubestock, and direct seeded are shown in Table 4 and Figure 5. An additional 5.4 ha outside of the main restoration sites was planted with trees only (mostly *Banksia attenuata*) in areas that failed to regenerate well after a fire in 2008 (orange area in Fig. 5). In addition to BWR project plantings, Greening Australia WA manages two more restoration sites at Forrestdale Lake as part of a Western Power offset. Additional planting and weed management is likely to be required for several years, especially in weed dominated areas at the edges of restoration sites.

B. Anketell Road

Areas at the Anketell Road site spread with topsoil transferred from Jandakot Airport in 2012 and those areas planted or direct seeded are shown in Figure 6. Rabbit-proof fencing extends around most of the spread topsoil. These fenced areas were planted with tubestock in 2012, 2013 and 2014 (Fig. 6). In 2014, 12 ha of additional land outside areas with transferred topsoil, but suitable for banksia woodland restoration was fenced, direct seeded and planted and several other areas were only planted (Fig. 6, Table 4).

C. Pony Place

In 2013 and 2014, a small 0.3 ha area adjacent to the Anketell North section of Jandakot Regional Park was planted to restore transitional banksia woodland using species listed in Table 2. The purpose of this trial is to investigate the feasibility of restoring banksia woodland in pastures with highly fertile soils and a long history of intensive grazing.

Table 4. Banksia Woodland Restoration Actions by Area (areas for some activities overlap).

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
	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**

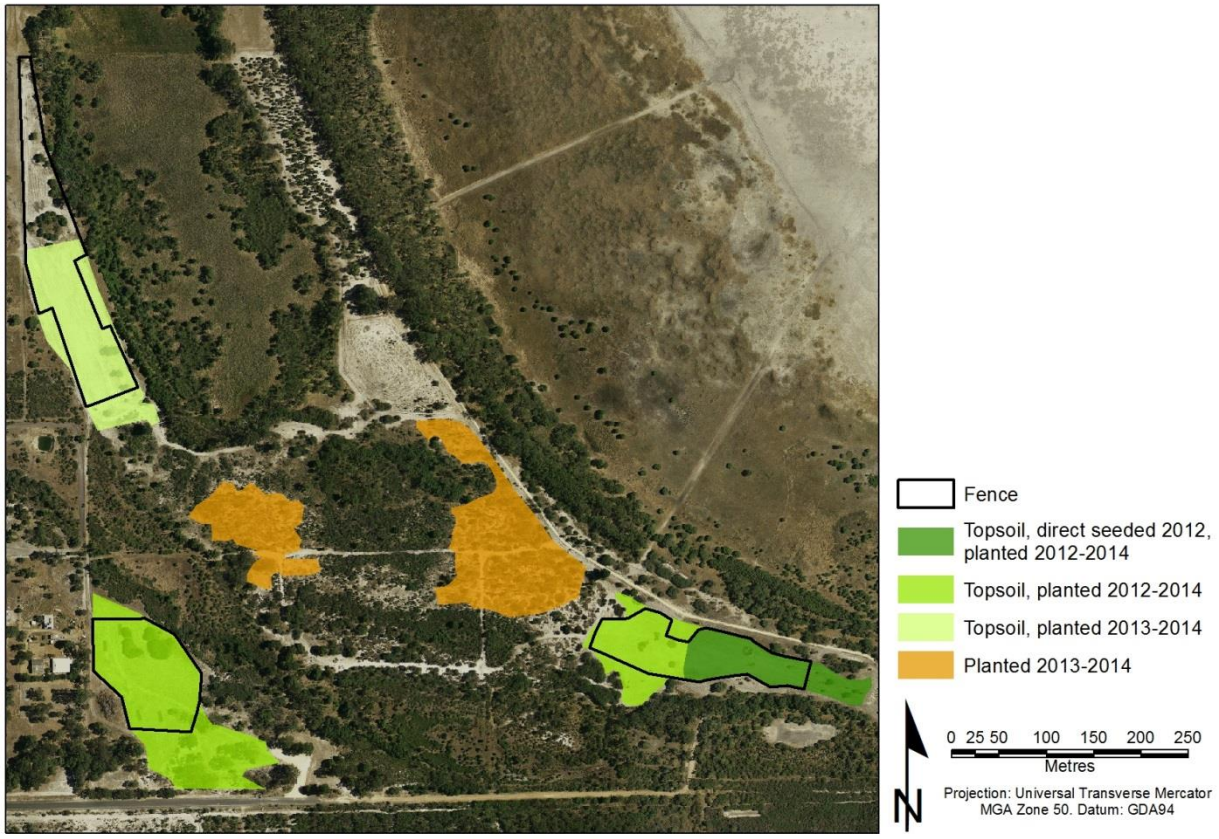


Figure 5. Forrestdale Lake restoration site showing total areas fenced, direct seeded and planted in 2012-2014.

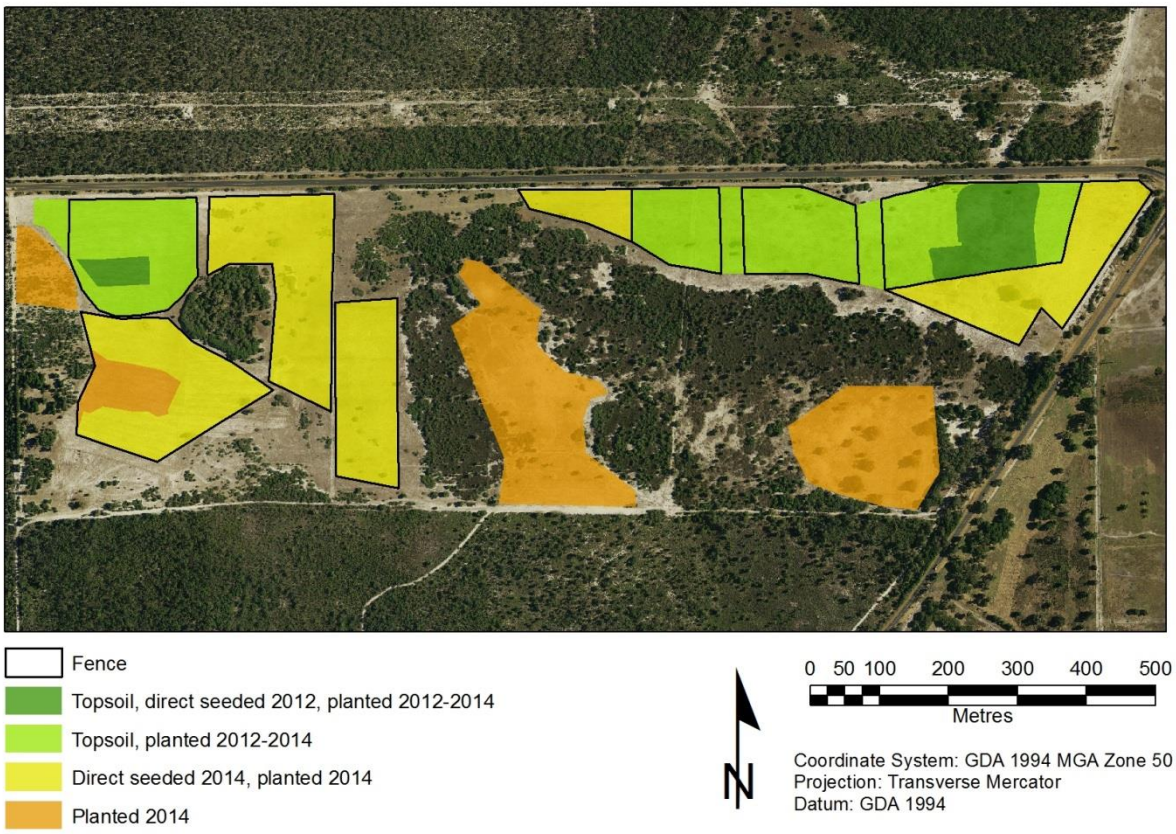


Figure 6. Anketell Road restoration site showing total areas fenced, direct seeded and planted in 2012-2014.

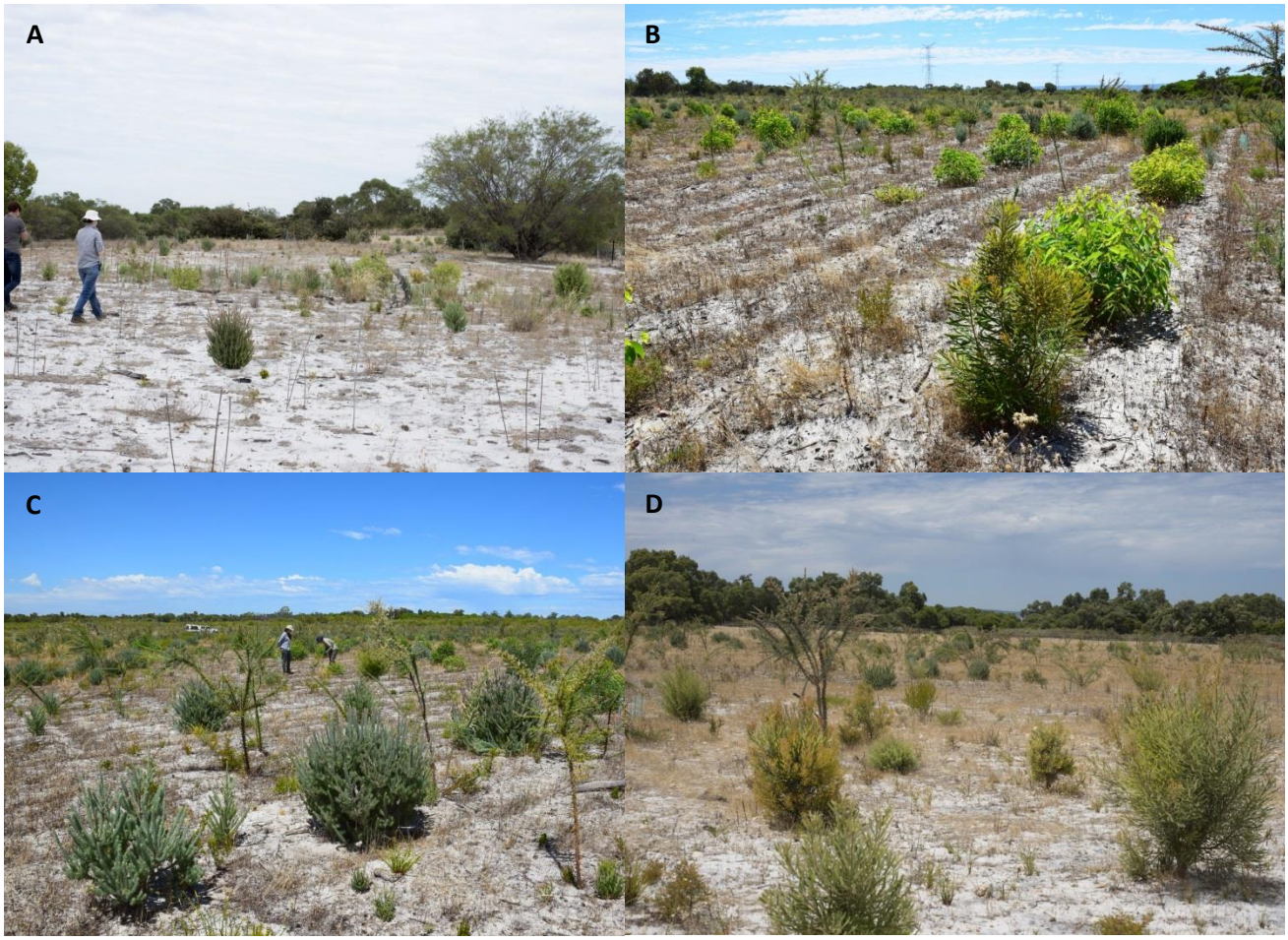


Figure 7. Vegetation at the Forrestdale Lake (A) and Anketell Road (BCD) restoration sites after 3 years. **A**. Vegetation at Forrestdale Lake showing both sparse and dense areas. **B**. Trees resulting from a 2012 direct seeding trail at Anketell Road. **C**. Large shrubs become more dominant in 2014 in the west end of Anketell Road. **D**. Banksia trees and scattered large shrubs growing at the east end of Anketell Road. There are also many small native plants that are not easily visible in these images. These photos were taken in summer when annual native plants and most weeds are inactive.

Figure 8. Examples of native plants growing from respread topsoil that flowered in 2014. **A**. large clump of the cowslip orchid (*Caladenia flava*), **B**. *Croninia kingiana* (Ericaceae), **C**. Catspaw (*Anigozanthos humilis*).

5. Monitoring Survival and Recruitment in Restoration Areas

Monitoring of restoration areas for comparison with the completion targets in Table 5 required a combination of 4 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 native plants over 20 cm in size and larger weeds. They are arranged in groups of 4 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. 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. 9AB). Cover of annual weeds and annual native plants was initially much higher than perennial species and 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. 9AB).

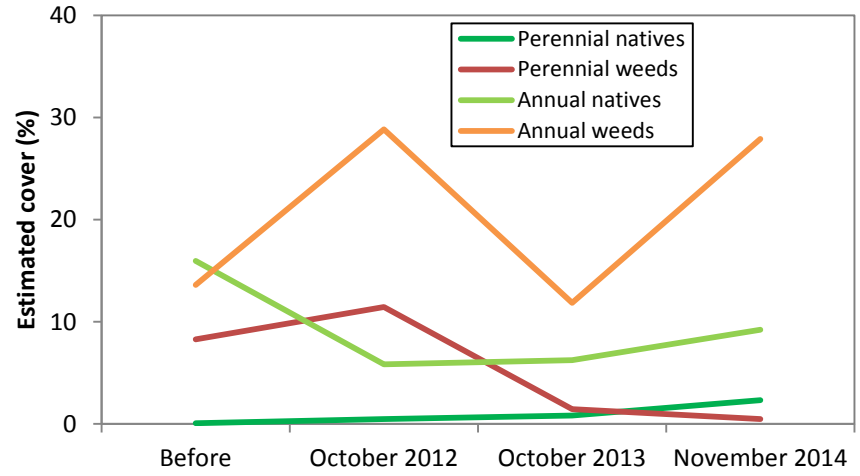


Figure 9A. Changes in the cover of categories of plants at the Anketell Road restoration area. Results are from immediately before topsoil was spread and for the first 3 years after germination and planting of native plants commenced. Native plant cover at this site is dominated by *Podotheca gnaphalioides* which is an annual disturbance opportunist.

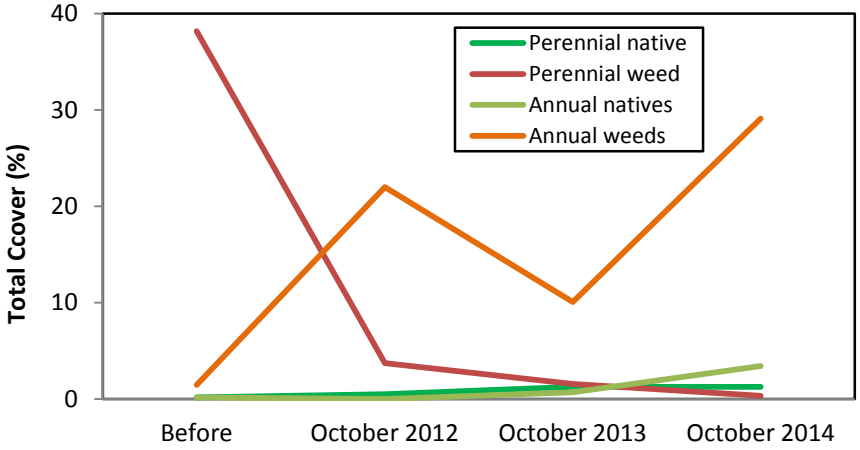


Figure 9B. Changes in the total cover of plants at the Forrestdale Lake restoration area over time. There were fewer annual native plants and annual weeds at this site initially. Weed control has greatly reduced the cover of perennial weeds (predominantly veldt grass).

5.2. Plant Density

As shown in Figure 10, total native plant density, which is primarily from topsoil seed germination, peaked at over 700,000 stems per ha in 2013. However, many small native plants were killed by severe drought in the summer of 2013/2014, resulting in about 27,400 native perennials per ha by late 2014. However, this lower density was still sufficient to meet restoration targets (Table 5). The density of weeds was very high initially at 1-2 million stems per ha (Fig. 10) and is slowly reducing. Survival of nursery-grown seedlings planted in 2013 was also much lower than anticipated in "the driest summer on record" in 2013/2014, but a substantial number were still alive in 2014 (Fig. 11). After planting to replace missing trees and perennials in 2014 (Table 2), plant density was adequate, except at one area at Anketell Road and two areas at Forrestdale Lake that require additional planting or seeding in 2015 (Fig. 11). Most surviving tubestock are now growing well. 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 2015.

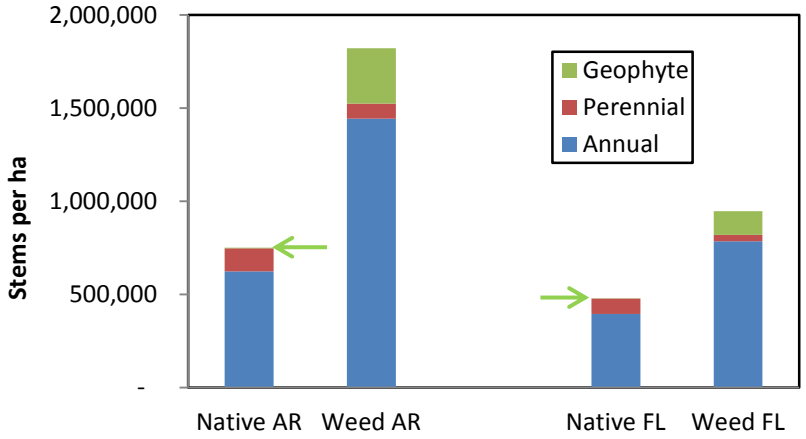


Figure 10. The average density of all native plants and weeds at Anketell Road (AR) and Forrestdale Lake (FL) restoration areas measured in October 2013 (data from 113 plots of 1 x1 m). These results include small native plants, seedlings and annual weeds that were not counted in larger plots (e.g. Fig. 11). The density of native geophytes was relatively low (arrows).

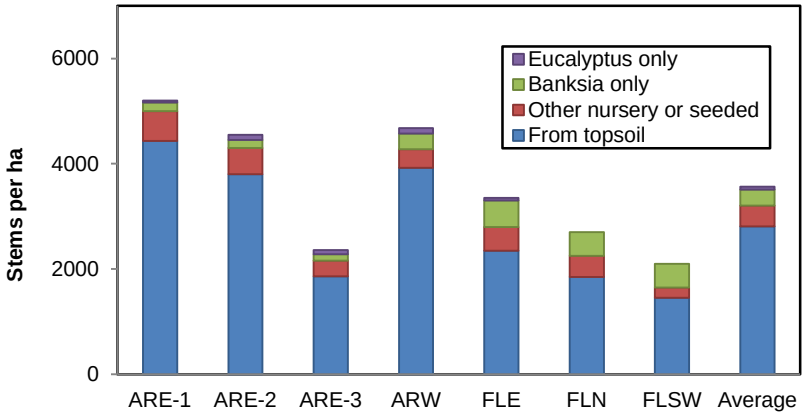


Figure 11. The average density of all large perennial native plants (>20 cm) after planting concluded in 2014. Nursery-raised or direct seeded native plants and those growing from topsoil are shown separately. Data are averages from 80 of the 5 x 5 m monitoring plots averaged across 8 separate areas at 2 sites. (AR = Anketell Road, FL = Forrestdale Lake, E = east, etc.).

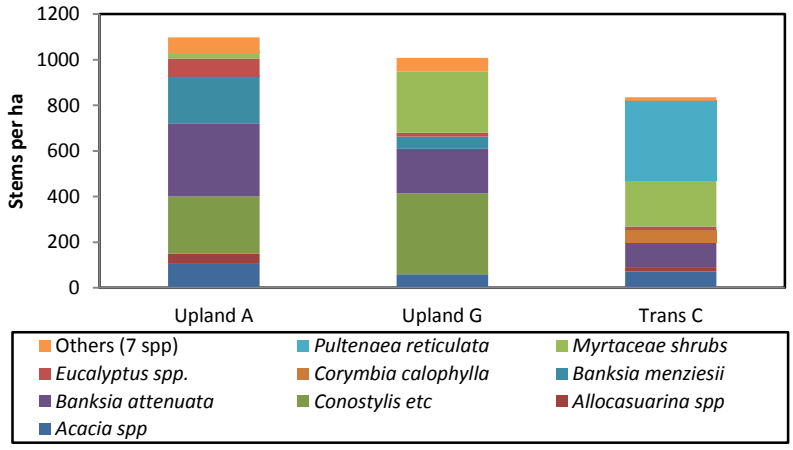


Figure 12. Preliminary germination data for direct seeding in 2014 showing the relative contribution of different species or groups of plants (similar looking seedlings). Data are for three of the largest direct seeded areas. The total area seeded in 2014 was 12 ha (Trans = transitional dampland area).

As shown in Figure 11, native plant density is dominated by annuals and perennials from the respread topsoil. Geophytes, which presumably grew from tubers or roots transferred in topsoil, were also present (Fig. 10). Geophytes that flowered in 2014, included sundews (*Drosera* spp.), lilies such as *Chamaescilla corymbosa* and native orchids such as *Caladenia flava* (see Fig. 8).

Direct seeding of 12 ha by Greening Australia in 2014 resulted in substantial numbers of banksias, eucalypts and shrubs, but overall plant densities are much lower than recruitment from topsoil (Fig. 12). Planting of tubestock also occurred in these areas. 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 other areas. We plan to apply additional seed in areas with low plant density in 2015.

5.3. Plant Diversity

After only 3 years, the total diversity of native plants at both Anketell Road and Forrestdale Lake is similar to that found in reference sites, with over 150 native plants found at both sites (Appendix 2). The diversity of plants in 10 x 10 m plots is approaching targets based on reference plots after 3 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. 13), but most are native plants from the topsoil that are most common after disturbances such as fire. These include annuals such as species of *Austrostipa, Podotheca* and *Trachymene* and several small shrubs that were initially abundant (e.g. *Hibbertia subvaginata* and *Bossiaea eriocarpa*). These plants declined in numbers by year 3, 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 typically senesce several decades later, remaining 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 been observed in restored areas yet. There are over 80 species of weeds present in restoration areas, the majority of which are of limited concern (small annuals which are shade intolerant).

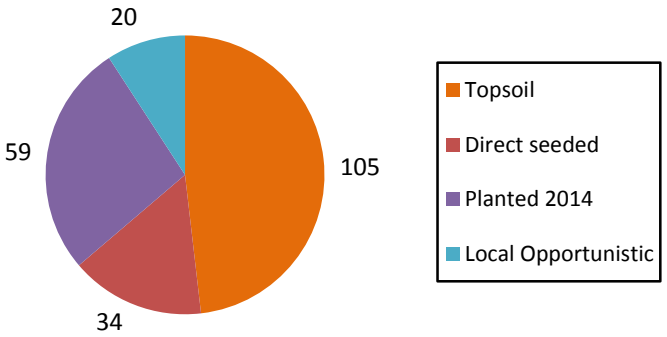


Figure 13. The relative proportions of native plants recruited from different propagation sources. There is some overlap between categories and there are only 150 species in total. These Species are listed in Appendix 2.

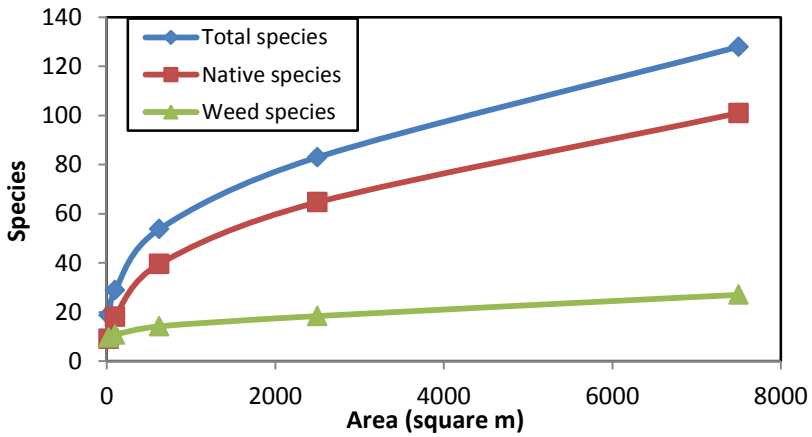


Figure 14. Species area relationships measured using nested plots, 5, 10, 25 and 50 m square at Anketell Road. This relationship shows how apparent diversity increases with the size of areas monitored. Monitoring only needs to find 60% of species (target diversity) and should not greatly exceed the area surveyed in reference sites (2000 m^2).

One of the greatest challenges in restoration monitoring is to sample areas with sufficient replication to measure diversity accurately, without exceeding available time and resources. The number of plots of different sizes required can be determined by calculating species area relationships using nested plots of increasing sizes. Figure 14 shows that an impractically large area was needed to detect 100 native plant species out of the 150 known to occur at this site. The remaining species are relatively uncommon, so are unlikely to be detected in monitoring plots of any size. This species accumulation curve analysis determined that the areas being monitored are adequate to monitor diversity targets (60% of reference site plants).

5.4. Restoration Outcomes Relative to Targets

Restoration outcomes relative to completion targets are summarised in Table 5. After 3 years, most diversity targets have been reached, but seed germination from the topsoil was highly variable so there are some areas with more weeds than natives. As illustrated in Figure 13, the topsoil seed bank provides about half of 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 before the current summer, but this will be reassessed in 2015. 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 3 years, of which many were perennials (Appendix 2). Substantial pollinator activity and seed set was observed at both 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 includes 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 and will be reviewed annually. Topsoil transfer was the most efficient for restoring native plant diversity, but planting or seeding was also required to establish trees and some shrubs.

Table 5. Restoration outcomes relative to targets set to assess vegetation in restoration sites.

Criteria	Target	Status in late 2014
Total species richness	Maximise native species richness *There were **>80 species** present in reference quadrats*	**Over 150** native species (highly variable spatially)
Average species richness per 10 m 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).*	**7 to 34** species per quadrat (average 18)
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)
Tree density	Establish at least **300** stems/ha	**357** per ha
CBC food plants	This consists primarily of banksias - **250** stems per ha	**305** per ha
Average understorey species richness per 10 m x 10 m quadrat	Return 60% of average number of native understorey species in reference quadrats (**17 species**). *There were 25-36 native understorey species per reference quadrat (average 29).*	**6 to 33** species per plot (average 16)
Total density of native perennial plants	Establish **7,000** stems/ha	**24,000 - 31,000** per ha
Density of large understorey plants	Part of the 7,000 stems/ha overall target	**2,700 - 4,200** per ha, highly variable and still increasing
Annual native plants	No target set and very much lower in reference sites	**>500,000** per ha
Key understorey 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 weed cover remains high

6. Rehabilitation of Habitats by Weed Management and Fencing

The highest priority BWR sites on the Swan Coastal Plain for weed control and other management actions are listed in Table 6. These areas were prioritised by strategic assessment, site visits and weed mapping in 23 reserves, of which 16 were newly mapped for this project. Weed management work commenced in 2013 for perennial veldt grass (*Ehrharta calycina*) and other highly invasive weeds. Large areas have also been 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. The weed management objectives set by the BWR project are:

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 (Section 2).
4. Undertake management to maintain and/or increase bushland condition.
5. Ensure weed management fits within existing strategic management processes.

In total, over 900 hectares of banksia woodland was mapped using a DGPS for 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. The weed species mapped with the widest distribution was *Ehrharta calycina* (perennial veldt grass) and approximately 322 ha were sprayed to control it in 2014. In most cases there were clear benefits visible within a few weeks, as suppressed native plants become visible (Fig. 17). We worked closely with contractors to ensure weed control was highly effective in 2014, by careful specifications of the timing for spraying, areas to be sprayed and methodologies used. We plan to re-assess and respray areas in 2015 to ensure weeds do not regain dominance from surviving individuals or seed. In total, 20 bushland areas and two restoration sites had weed control works funded and managed by the BWR project in 2014 (see Fig. 15 and Table 6):

1. The two restoration sites, Anketell South and Forrestdale Lake were sprayed to manage perennial veldt grass and other major weeds including broad-leaved annuals (see Section 4). Hand removal or spraying of lupins, pigface, watsonia, *Euphorbia terracina,* woody weeds, (including figs, *Acacia* sp. and Victorian tea tree) and arum lily also occurred at these sites.
2. A total of 233 hectares was sprayed in Regional Parks primarily for veldt grass control in 2014 (Anketell North, Anstey Keane, Harrisdale Swamp, Lake Kogolup, Piara Nature Reserve and The Spectacles). However, Shirley Balla Swamp was managed using special funding available to Regional Parks post fire in 2014. Spraying at several reserves remains incomplete due to re-prioritisation, (Anketell South), or access problems (Fraser Road). Fraser Rd will be sprayed for veldt grass in 2015 to protect the large population of *Caladenia huegelii* within the reserve.
3. Weed control to manage outbreaks of other major weeds including golden wattle (*Acacia longifolia*), watsonia, freesias, *Euphorbia terracina* and arum lily at the same reserves also occurred (Table 5). Additional follow-up spraying for these weeds was organised following the fire in Shirley Balla.
4. A total of 90 hectares of veldt grass was sprayed in Swan Coastal District reserves (Hawkevale Nature Reserve, 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 hectares for veldt grass and *Euphorbia terracina* in Denis de Young Reserve.
6. A major dolichos vine (*Dipogon lignosus*) outbreak at Harrisdale Swamp that was smothering trees was successfully controlled (see Fig. 16). This required several herbicide applications to cut stems by a contractor and regular follow-up treatments by staff.
7. Where possible, small outbreaks of weeds that provide a major threat to nature reserves have been dealt with by staff or contactors. These weeds include opuntioid cacti and other succulents, pampas grass and eastern-states eucalypts.

In addition to perennial veldt grass, *Euphorbia terracina* (Geraldton Carnation weed), *Freesia alba x leichtlinii* (Freesia), *Babiana angustifolia* (Babiana), *Moraea flaccida* (Cape tulip), *Lachenalia reflexa* (Yellow soldiers), *Watsonia meriana* var. *bulbillifera* (Watsonia) and *Zantedeschia aethiopica* (Arum Lily), *Nicotiana glauca* (tree tobacco) and numerous woody weed species have been targeted in the sites listed in Table 5. Each weed species has a specific biology which dictates timing and chemical applications required to achieve high mortality rates (florabase.dpaw.wa.gov.au). Spraying was carried out by 5 companies as specified in a panel tender. The minimum mortality rate of 80% is the standard set for the contractors. Weed control for the 2014 was more successful than in 2013 and met most of the main objectives with a total of 500 ha managed for major weed infestations. This year we worked closely with Regional Parks, predominantly in Shirley Balla Swamp after the devastating fire went through in February 2014. The *Dipogon lignosus* control in Harrisdale Swamp has been controlled by contractors to a point in which the Conservation Employees working for Regional Parks can manage it within their works programs.

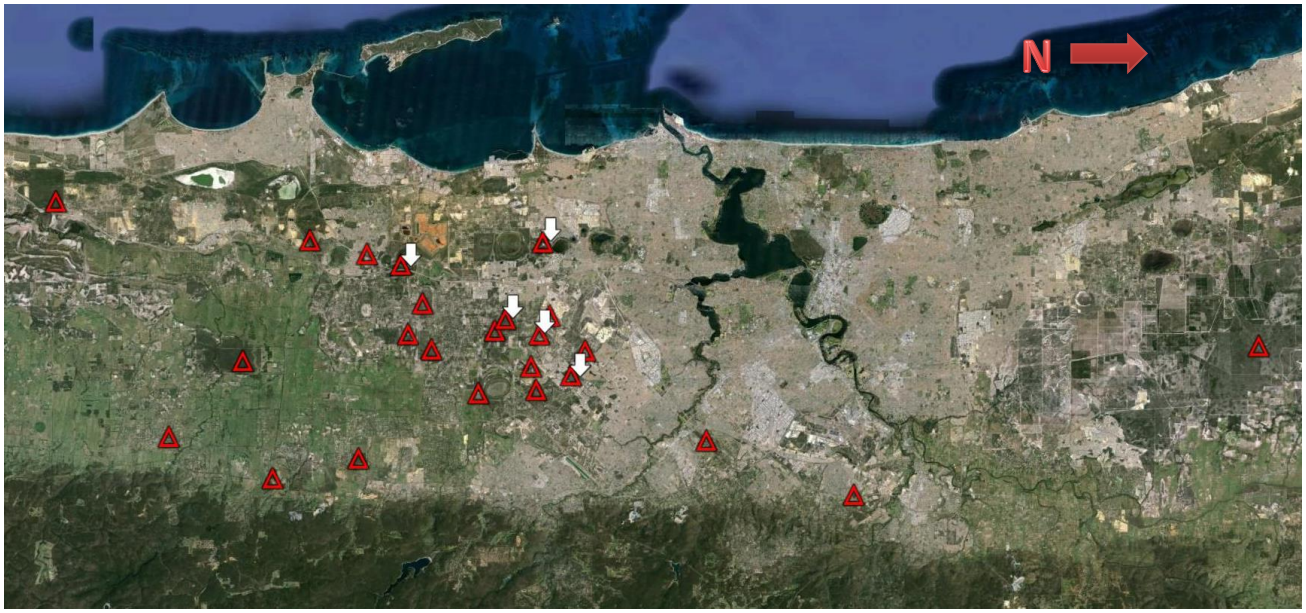


Figure 15. Areas where weed management funded by the BWR project occurred from 2012 to 2014 (red triangles). Locations of monitoring plots for perennial veldt grass control are also shown (white arrows).

Figure 16. Dolichos vine (*Dipogon lignosus*) infestation at Harrisdale Swamp before (left) and after (right) control. Melaleuca trees that were smothered are showing signs of recovery.

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 objectives
Anketell Rd North, Jandakot Regional Park (BWRP)	1	347	204	50		Veldt grass control, freesia, arum lily, woody weed removal
Anketell Rd Restoration Site, Jandakot Regional Park (BWRP)	1	Adj. 347 & 348	18	20	2.5	veldt grass control, pigface sprayed (10 ha), hand removal pigface, euphorbia, bulbs, etc.
Wandi Nature Reserve, Jandakot Regional Park (UN, BWRP)	1	347	UN	20		Veldt, freesia, pigface to protect DRF
Melaleuca Park (SCD)	3	399	53	10	4	Euphorbia control, woody weeds and stoping illegal access 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	veldt grass control, hand removal of lupin, euphorbia, bulbs, etc.
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	0.35	Ongoing eradication of bulbs, bamboo, couch grass. in TEC, fences and gates
Dennis de Young Reserve, Jandakot Regional Park (City of Cockburn)	9	344	CoC	20		Veldt grass and euphorbia (also funded by City of Cockburn)
Anketell Rd South, Jandakot Regional Park (BWRP)	12	348	51	12 (24)		Veldt grass, hand weeding-euphorbia, pigface, gladiolus
Anstey/Keane Dampland, Jandakot Regional Park (UN, BWRP)	15	342	UN	50		Veldt grass, euphorbia, cape tulip, black flag, Victorian Teatree
Acourt Rd Regional Park, Jandakot Regional Park (BWRP)	19	389	67	20		Veldt grass, freesia, pampas grass, unauthorised access
Kogolup Lake, Beeliar Regional Park (BWRP)	21	391	60	56		Veldt grass, pigface, euphorbia, 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			1.4	Fencing and gates
Fraser Rd Bushland (SCD, BWRP)	37	390	20	11	2	Veldt grass control in Rare Flora habitat
Rose Shanks Reserve (in Fraser Rd Bushland) (City of Cockburn)	37	390	CoC	30		Veldt grass control, euphorbia
Leda Nature Reserve (SCD, BWRP)	42	349	80	28 (75)	2.5	Veldt grass in prescribed burn area, fencing
Harrisdale Swamp, Jandakot Regional Park (BWRP, RP, Friends of Forrestdale)	43	253	53	40		Veldt grass control, *Dipogon* sp. climber, euphorbia, pampas grass, Sydney golden wattle
Hawkevale Reserve (SCD, BWRP)	47	122	10	10	0.95	Veldt grass control, woody weeds, fencing and rubbish removal
Piara Nature Reserve, Jandakot Regional Park (BWRP)	63	262	36	15		Veldt grass, euphorbia, 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 and bulbous weed control, woody weeds
Lambkin Rd Bushland (SCD)	95	375	SCD	2		African love grass, watsonia, etc.
Total			**924**	**640**	**16.2**	

*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 that includes 31 permanent 10 x 10 m plots in five reserves where weed management is underway (Fig. 15). 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 and cover and tree canopy health, as well as fauna diversity (Section 9). The appearance of one of these plots before and after weed spraying is shown in Figure 17.

Figure 18 shows how after veldt grass is eliminated there is an increase in the visibility of native plants. Orchids were one of the first groups of native plants to respond to weed management, presumably due to their wind dispersed seeds, as more orchid seedlings were observed after weed control (Fig. 19). However, the most visible 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* (Figs. 18, 19, 20). The visual dominance of annual weeds is more due to increased visibility than to increased cover (Fig. 20). Small annual weeds are not considered to be of major concern, as they are smaller in stature than most native plants (Fig. 18). The overall dominance of weeds substantially decreased after spraying removed most perennial veldt grass (Fig. 21). Responses of other native plants to weed management will be measured during the next major survey in spring 2015 which will follow the third year of weed control. This monitoring also allows us to investigate problems with secondary weed invasion that occurs in some plots after spraying. These include bulbous weeds, such as watsonia and freesia, that will be monitored and further management of them will occur if necessary and feasible.

In addition to the BWR monitoring projects, a remote sensing approach to tree canopy and understorey vegetation cover and condition monitoring commenced in 2013 (coordinated by Ricky Van Dongen, Geographic Information Services, Parks and Wildlife). This monitoring occurs at three BWR weed monitoring sites, including the burnt area at Shirley Balla Swamp, as well as the Anketell Road restoration site. Photographs of fixed areas of the canopy and understory, detailed aerial photographs and satellite imagery are being used to measure vegetation density at regular intervals in this project. This methodology has been adapted by the BRW project and we are now routinely taking photographs of 1 m x 1 m and 10 m x 10 m plots that will be used to compare algorithm-generated cover measurements with our visual estimates of cover.

Figure 17. Changes to vegetation following successful control of perennial veldt grass at The Spectacles. These photos are from the same corner of a 10 m x 10 m quadrat. The left image is from the summer of 2012 before spraying when veldt grass flower spikes were a major component of the understorey (pale brown). The right image was taken after the second spray in spring 2014 and clearly shows the native vegetation that was formerly suppressed by weeds (green).

Figure 18. A 1 x 1 m quadrat at Harrisdale Swamp after the first selective herbicide application in 2013 (left) and the second spraying in 2014 (right). The first image shows abundant dead veldt grass (brown) around a native plant (*Dianella* sp). The second photo shows small annual weeds and the native cowslip orchid (*Caladenia flava* - arrows) that became prominent after weed management.

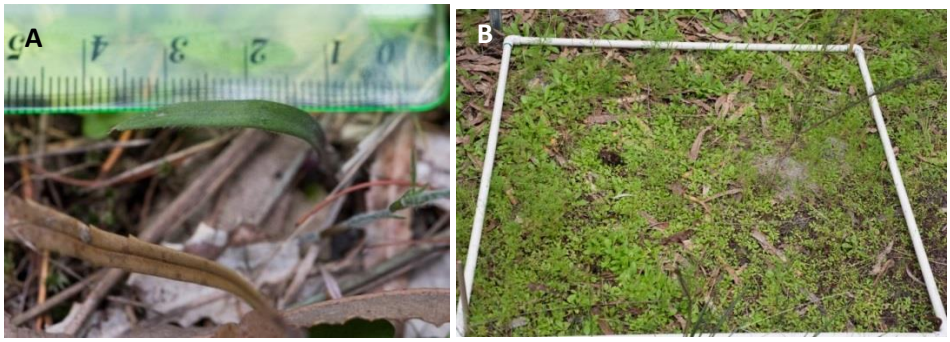


Figure 19. **A**. Seedling of *Caladenia flava*, one of the first native plants to respond to weed management. **B**. Small annual weeds were dominant (mainly *Hypochaeris glabra*) in a sprayed quadrat at Harrisdale Swamp (2014) after two years of spraying.

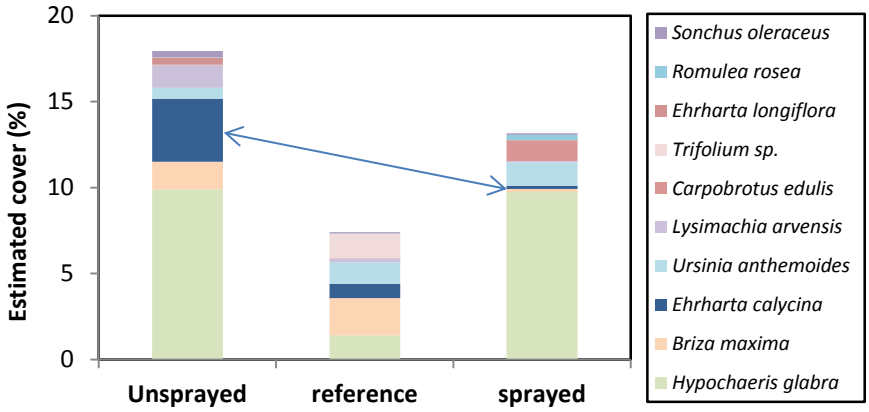


Figure 20. Impact of veldt grass spraying on the top 10 weeds in monitoring sites after two years of spraying. Annual weeds such as *Hypochaeris* and *Ursinia* appear more dominant after spraying greatly reduced cover of perennial veldt grass (*Ehrharta calycina*) (arrow). These are estimates of cover in five 1 m x 1 m plots within each 10 m x 10 m quadrat.

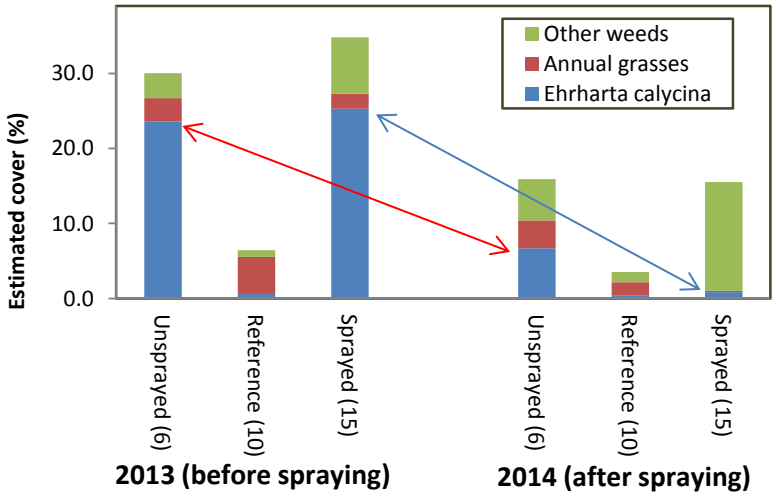


Figure 21. Changes in the cover of all weeds divided into categories based on spraying susceptibility. Weed control greatly reduced annual and perennial grass cover, (blue arrow) but increased the cover of some other weeds. The apparent decrease in veldt grass cover in unsprayed plots (red arrow) is primarily due to if sampling before rather than after flowering (the number of plants was similar). Cover values were estimated in the same 10 m x 10 m plots.

8. Monitoring the Recovery of Banksia woodland after Fire

A very severe wildfire in Banjup in February 2014 burnt all 7 BWR monitoring plots in Shirley Balla Swamp within Jandakot Regional Park (Fig. 22), 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 the remaining 24 plots to monitor weed management, but have since been used to monitor changes in plant density, cover and diversity after fire. This monitoring was monthly for the first 6 months and will continue less frequently in the future. Results for the first 8 months are summarised briefly here:

1. There was an initial 25% mortality of trees, with 23% resprouting from the canopy, 21% from the trunk and 33% from the base only, as shown for *B. attenuata* in Figure 23. Some resprouting trees have since died, so tree survival will be remeasured in 2015 once tree deaths have stopped.
2. Plant cover was very low for the first 6 months except for native grasses. Weed cover was much lower than native cover in year 1, especially in areas sprayed before the fire (Fig. 24).
3. Banksia seed germination is several orders of magnitude higher than in unburnt sites nearby, reaching >10,000 seedlings per ha (Fig. 25). Their survival will be reassessed after summer.
4. More plant species recovered by seed germination than by resprouting, but the latter resulted in more cover (Fig. 26). Eight months after the fire the total diversity of native plants was similar to before the fire (120 species were present in the 7 plots), but the composition of species was altered by the recruitment of fire responsive species only present as seed before the fire.
5. There were major benefits of weed control after the fire since perennial veldt grass cover was <5% in sprayed areas but increased following fire in unsprayed areas (Fig. 27).

Figure 22. Loss of vegetation immediately after the fire in Shirley Balla Swamp (top left) and partial vegetation recovery 8 months after the fire (bottom left). The remaining photos show resprouting plants of *Macrozamia* sp. (top middle), *Xanthorrhoea* sp. (top right), *Banksia attenuata* (bottom middle) and *Banksia menziesii* (bottom right) several months after the fire.

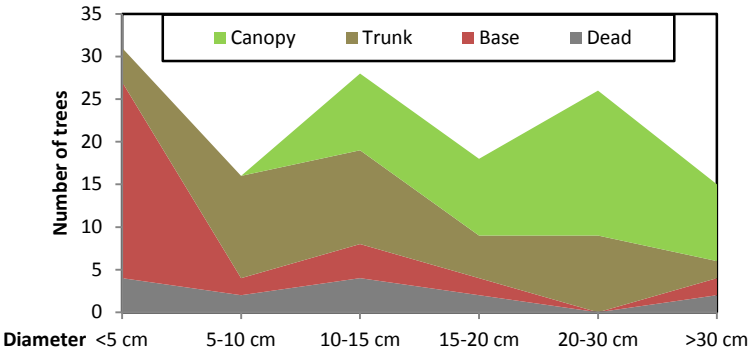


Figure 23. Recovery of candle banksia (*Banksia attenuata*) trees several months after the February 2014 fire at Shirley Balla Swamp. Results for *Banksia menziesii* were similar but there were very few trees over 30 cm in diameter. Overall 23% of trees were killed, 23% resprouted from the canopy, 21% resprouted from the trunk and 33% resprouted from the base only.

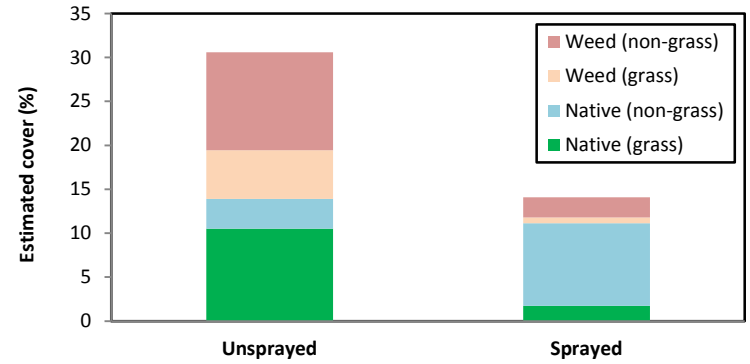


Figure 24. The cover of native plants and weeds 10 months after the fire in Shirley Balla Swamp in areas with or without spraying of herbicides to manage weeds. Native understorey plant cover only became substantial after 6 months and a native grass became dominant in some areas after the fire (*Austrostipa compressa*).

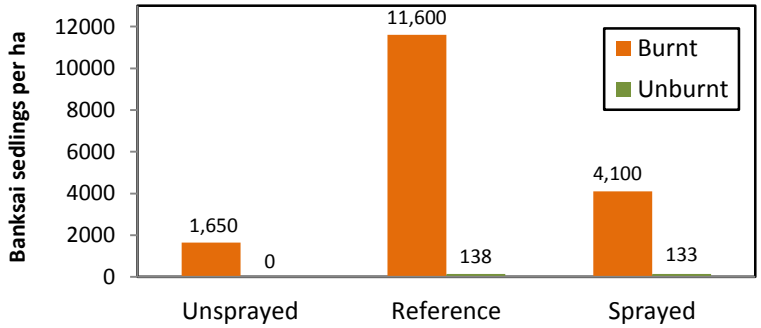


Figure 25. Banksia seedling germination was very high in the burnt site in 2014 and also seemed to benefit from veldt grass control, as it was substantially lower in all unsprayed plots. Seedlings are primarily *Banksia attenuata* and *B. menziesii*. Note that data from unburnt sites was collected in 4 different reserves to show typical values for that year.

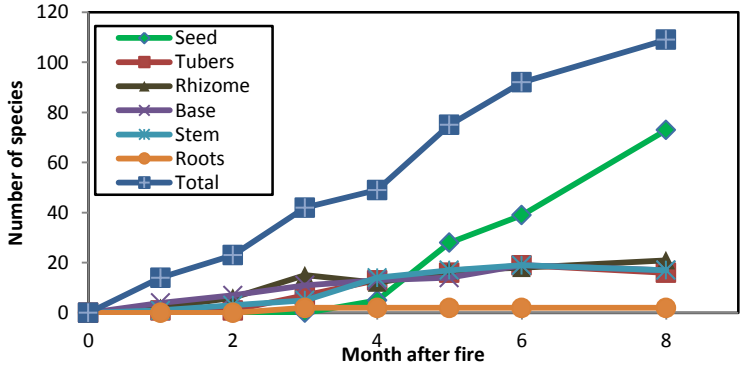


Figure 26. The relative importance of different native plant regeneration strategies after fire. This graph shows the species richness of plants which resprouted from stems, rhizomes, tubers and roots, or grew from seeds. Resprouting plants dominated initially and those which recruited from seed started to became important in winter (month 4).

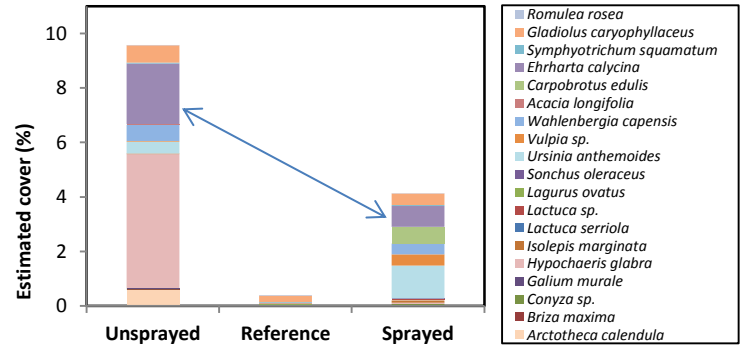


Figure 27. Weed cover 8 months after the fire in Shirley Balla Swamp. The sprayed plots had lower overall weed cover and reduced veldt grass dominance (arrow). Reference plots were also unsprayed but had very low weed cover initially.

9. Monitoring Fauna in Restoration and Weed Management Sites

A fauna monitoring program commenced in 2012 with the aim of observing key species such as the Carnaby's cockatoo and the southern brown bandicoot. In addition to the key species, terrestrial vertebrates, ants and pollination events are being monitored at six sites (restoration and weed control). This will help to ascertain whether the restoration of completely degraded sites or weed control in existing banksia woodland improves the quality of existing habitat or creates additional faunal habitat.

Monitoring for black cockatoos, macropods, southern brown bandicoots, ant functional groups, pollination activities, birds and other terrestrial vertebrates continued for a second year in 2014. Southern brown bandicoots and black cockatoos were only noted in the reference sites, whereas macropods are present at all monitoring sites. Ant functional groups have increased from year one to two in the restoration sites, approaching the predicted number of functional groups for the restoration age (Moore and Barrett 2013). As expected, bird species richness was higher in the reference sites than the restoration sites over the two years of monitoring. Camera traps were also deployed and detected additional mammals (including feral predators), reptiles and birds at all sites. Pollination of native plants was observed at all sites.

Trapping for mammals, reptiles and amphibians was carried out in spring 2014 using pitfall and cage traps at treatment and reference sites within Anketell Road Bushland, Forestdale Lake and Rose Shanks Reserve (six trapping grids in total). As expected, there were few mammals, with only the southern brown bandicoot (in reference sites) and house mouse (*Mus musculus*) captured. A total of 20 reptile species were captured across the six trapping grids. Similar numbers of reptile species were seen in restoration and reference sites, but more individuals were captured in the reference sites. Six amphibian species were captured, which is higher than expected in these habitats, but only two of them were found in the restoration sites. Examples of fauna observed or captured in traps are shown in Figure 28.

Lastly, Rapid Bushland Assessments are being undertaken in both restoration and some perennial veldt grass management sites (Moore and Barrett 2013). Rapid Bushland Assessments form part of a larger monitoring program across metropolitan habitats.

Figure 28. Fauna monitoring in 2013 and 2014 with examples of animals observed or captured.

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. 29). These grants used funding from the Jandakot Airport offset for projects to run between June 2014 and September 2016. There were 20 successful grant recipients working in 20 project locations from 35 applications (Table 7). Grants were from $5,500 to $22,000 with a total value of $327,000 (with GST), excluding in-kind contributions. There were 11 projects to restore banksia woodland habitats, 4 to manage weeds and 5 for *Phytophthora* dieback management, as listed in Table 7. The locations of these projects are shown Fig. 30. The BWR project also provided seed of banksia woodland plants to a number of these community groups.

Table 7. Successful recipients of Banksia Woodland Community Restoration Grants in 2014.

Organisation	Project Title	$ Funding (ex GST)
Baldivis Children's Forest	Baldivis Banksia Woodland Wonderland with Baldivis Children's Forest	$18,000
Birdlife Western Australia	Revegetating the Eastern Gateway for Carnaby's	$20,000
Ellen Brockman Integrated Catchment Group	Managing Phytophthora cinnamomi in Bullsbrook Nature Reserve	$18,970
Friends of Hepburn and Pinnaroo Bushland, Inc.	Control of Moraea flaccida (One leaf Cape Tulip) and Gladiolus caryophyllaceus Weeds in the Hepburn Heights Conservation Area	$18,540
Friends of Ken Hurst Park	Restoration of degraded areas in Ken Hurst Park	$12,275
Friends of Maida Vale Reserve : Banksia Woodland Restoration Project	The Friends of Maida Vale: Banksia Woodland TEC Restoration Project	$12,800
Friends of Queens Park Bushland	Maniana Reserve Revegetation Project	$9,981
Greening Australia	Peel Biolinks - Connecting Landscapes for the Future	$20,000
Landcare Serpentine Jarrahdale, Inc.	Banksia Ridge Dieback Treatment and Mapping	$6,000
Landcare Serpentine Jarrahdale, Inc.	Thompson's Dieback Treatment Project	$8,655
Landcare Serpentine Jarrahdale, Inc.	Elliott Banksia Woodland Dieback Treatment	$20,000
Landcare Serpentine Jarrahdale, Inc.	Banksia Ridge : Removal of Eucalyptus camaldulensis	$13,100
Murdoch Environmental Restoration Group (MERG)	Ecological Integrity and Black Cockatoo Habitat in Banksia Woodland Reserve Murdoch University	$20,000
North Swan Land Conservation District Committee	Weed Control and Dieback Phytophthora management of Banksia Woodland in West Bullsbrook	$14,955
South East Regional Centre for Urban Landcare, Inc. and Friends of Pagannoni Swamp	Foliar spraying to control Phytophthora cinnamomi on the eastern boundary of Paganoni Swamp Reserve	$19,360
The Friends of Shenton Bushland, Inc.	Restoring "The Barrens" as Cockatoo Habitat	$20,000
The Friends of the Spectacles	The Friends of the Spectacles - Banksia Woodland Revegetation Areas	$20,000
The Montessori School	Montessori Weed Control	$5,060
Waterbird Conservation Group	Rehabilitation of Cockatoo Habitat Canning River Regional Park	$5,000
Waterbird Conservation Group, Inc.	Banksia Woodland Restoration on a sandy rise adjacent to Maramanup Pool, Baldivis	$20,000

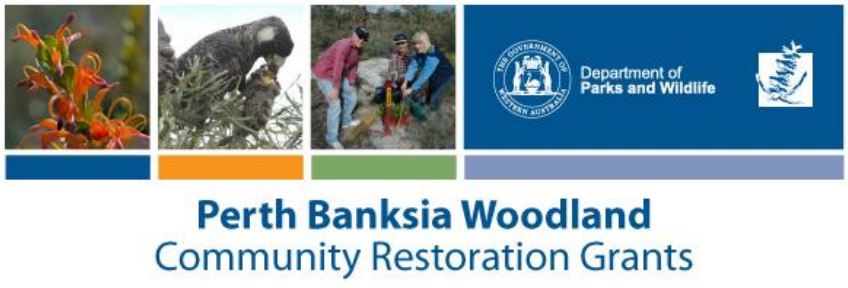


Figure 29. Logo for the community grants programme.

Figure 30. Locations of projects funded by Perth Banksia Woodland Community Restoration Grants (see Table 7).

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

One of the main focuses of the BWR project is to manage habitat of 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 and the next spraying at Fraser Road bushland has been postponed until 2015 because road works impacted on site access. The BWR project is also providing support for translocation of *Caladenia huegelii* into Jandakot Regional Park from a development at Wandi. Project staff contributed to 6 rare flora surveys in the area in 2014, including a survey in October 2014 that located a new population of an endangered donkey orchid (*Diuris purdiei*) in Jandakot Regional Park. The BWR project also provides financial support to the Friends of Ken Hurst Park to restore habitat 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 project aimed to determine whether these survivors are disease escapes (never infected) or resistant (able to restrict invasion). This was determined by measuring the radial extent of sapwood invasion following inoculation of the pathogen in the laboratory, relative to *B. speciosa* (a highly susceptible positive control). Potential resistance was tested using excised branches from 15 banksias (three *B. menziesii* and nine *B. attenuata,* three of which were tested twice) from two infested sites (Hakea Prison and Anketell Road). Branches were sampled between April and October in 2014. Branches were wound inoculated with a *P. cinnamomi* isolate from Jandakot airport, incubated at room temperature (21° C) for 7 days, cut into pieces with a band saw, plated onto phytophthora-selective agar and growth of *P. cinnamomi* assessed after 7 days. 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. Additional research is required to investigate this further (all trees were tagged and geo-referenced).). The BWR project has also collected 48 samples of seed at 4 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 2014 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 (Barbara Wilson), Regional Ecologist (Geoff Barrett), District Nature Conservation Coordinator (Craig Olejnik), Acting Manager Regional Parks Unit (Shawn Debono) and BWR Senior Ecologist (Mark Brundrett). Meetings are held every 3-5 months to organise finances, staffing, collaborations with other organisations, etc. 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 and the Malaga wetland offset project. Membership of this committee is listed in Table 8 and meetings are held every 6-12 months (Nov 2011, May 2012, Nov 2012, Oct 2013 and June 2014). Advice from this committee primarily concerns:

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

The principal stakeholders for this project are the Commonwealth Department of the Environment and Jandakot Airport Holdings. In addition to the Banksia Woodland Community Restoration Grants scheme, the BWR project has developed partnerships with community groups and local governments to help manage banksia woodland areas as listed in Section 14. Major outcomes from the BWR project relative to objectives and tasks are briefly summarised in Table 9.

Outcomes of the BWR project will also be presented in a series of reports concerning (i) site selection, (ii) baseline surveys at Jandakot Airport, (iii) restoration targets for flora in revegetated areas, (iv) fauna monitoring, (v) outcomes of weed management and (vii) fire impacts. Site specific reports detailing operations have also been developed for each of the areas where restoration or weed management occurs.

Table 8. Members of the Scientific Advisory Committee in 2014.

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
Dr. Barbara Wilson	Acting Regional Leader Nature Conservation, Swan Region
Dr. Geoff Barrett	Regional Ecologist, Swan Region
Dr. Mark Brundrett	Senior Ecologist BWR Project, Swan Region

Table 9. Banksia Woodland Restoration Project objectives and outcomes to December 2014.

Task	Objectives	Completed
I. Administration		
1. Filling Positions	Fill Senior Ecologist, Conservation Officer, Operations Officer, Survey Botanist roles	Five positions filled 2011 -14 and existing staff allocated tasks
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 continued in 2014
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	Seeds for 2015 planting sent to nursery and collection underway. Seed quality data obtained
11. Nursery seedlings and cuttings	Produce sufficient tubestock of banksia woodland plants for restoration sites	18,000 seedlings grown and planted in 2014, planning for 2015 planting
12. Direct seeding and planting native plants	Investigate effectiveness of direct seeding and planting for banksia woodland establishment	Seeding trials in 2012 successful (3 ha), 10 ha seeded in July 2013, 12 ha in 2014
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	Panel tender spraying of 20 reserves, from May 2013 onwards (about 330 ha) 2 years of work completed
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 Birdlife Australia volunteers July 2014. Community grants scheme provided $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 in 2011. Staff attended 5 rare flora surveys in 2014
19. Scientific research program	Research to measure and optimize plant and animal diversity in restoration sites	Scientific collaboration for 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 2014

A. Presentations

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

1. Perth branch of the Wildflower Society (April 5, 2014).
2. Southwest Orchid Conservation Group orchid propagation workshop, Bunbury (May 10, 2014).
3. Commonwealth EPBC Banksia Woodland meeting and trip (May 23-25, 2014).
4. Black cockatoo recovery team meeting (August 13, 2014).
5. Jandakot Regional Park Advisory Committee (August 26, 2014).
6. International Association for Vegetation Science meeting in Perth (September 5, 2014).
7. Northern Suburbs Branch of the Wildflower Society (November 25, 2014).
8. West Australian Native Orchid Study and Conservation Group orchid identification workshop (taught by Margaret Collins and Mark Brundrett) (December 13, 2014).

B. Publications and Media Statements

1. Brundrett M, Clarke K, Vanda Longman V. 2012. Setting comprehensive and effective completion criteria for banksia woodland restoration. *Society for Ecological Restoration Australasia Conference*, Nov 2012.
2. Brundrett M, Clarke K, Vanda Longman V. 2014. Setting comprehensive and effective monitoring targets for banksia woodland restoration and management. In: Mucina L, Price JN & Kalwij JM (eds). *Biodiversity and Vegetation Patterns, Processes, Conservation.* p. 72. Kwongan Foundation, Perth, Australia.
3. Brundrett M. 2013. Creating New Flora and Fauna Habitats on the Swan Coastal Plain. *Bushland News*, Issue 85, p. 5. Autumn 2013.
4. Taylor K. 2014. Controlling Dolichos pea (*Dipogon lignosus*) at Harrisdale Swamp. *Bushland News*, Issue 91, p. 3. Spring 2014.
5. Brundrett M. 2014. The Banksia Woodland Restoration Project. *Bushland News*, Issue 90, p. 10. Winter 2014.
6. *Cockburn Gazette*. July 22, 2014. Banksia woodland takes shape. Creating new habitat for Carnaby's cockatoos.

C. Partnerships

1. The BWR project is working with Greening Australia WA to jointly manage the Forrestdale Lake restoration site.
2. The Friends of Forrestdale helped plant tubestock and monitor restoration areas (see Cockburn Gazette).
3. Birdlife Australia provided volunteers for a planting day on Sunday June 22, 2014.
4. Provision of funding to the City of Cockburn to manage weeds in Jandakot Regional Park.
5. Seed supply to the Banjup Residents Group in 2014 for planting in burnt areas on private property.

15. References

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

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

Appendix 1. Monitoring Schedules for 2015

A. Monitoring schedule for restoration sites

Survey	Schedule	Site/s	Data collected	Purpose
1m x 1m quadrats	Annual October/November	Anketell Road Forrestdale Lake	Prior to October/November 2014: • Count and cover of all native and weed species • Overall percentage cover of natives and weeds October/November 2014 onwards: • Count and cover of perennial weeds and natives • Presence-absence of annual species • Overall percentage cover of natives and weeds (annuals and perennials)	• To assess native germinants emerging from transferred topsoil • To identify weed species and spread across sites and signal need for management • To track species richness and growth of natives over time from topsoil (and to a lesser extent from planting and direct seeding)
5m x 5m quadrats	Twice yearly April and September	Anketell Road Forrestdale Lake	• For perennials larger than 20cm only, count and foliage cover • For all plants (not just over 20cm) total cover for weeds and natives • For all Banksias, height and basal stem width • Presence-absence of all other species under 20cm	• To assess species composition across the restoration sites and compare to reference sites • To quantify the density and cover of perennial natives and weeds to gauge against completion criteria • To measure the survival and growth of Banksias, as food plants for Carnaby's cockatoo
Nested quadrats	Annual July/August	Anketell Road only	• Species richness (presence-absence data) • Count of planted and direct seeded plants	• To create a species accumulation curve • Provide data on plant density and tree cover
Direct seeding monitoring	Annual August/September	Anketell Road and Forrestdale Lake	• Number and species of seedlings emerging from the direct seeding rows, taken from a sample of rows	• To assess the success of the direct seeding and to monitor survival of seedlings
Photo monitoring	Twice yearly March and September	Anketell Road Forrestdale Lake	• Photographs taken at the beginning of autumn and spring at set photo monitoring points to allow for side-by-side comparison of photographs from year to year	• To provide a visual representation of the revegetation progress at the restoration sites

B. Monitoring schedule for perennial veldt grass management and post-fire response sites

Survey	Schedule	Site/s	Data collected	Purpose
Flora diversity, density & cover survey	Spring alternate years (10mx10m) Spring yearly (1mx1m)	All 31 veldt monitoring quadrats	1. Count & cover of perennial natives & weeds (10mx10m quadrats) 2. Count & cover of annual natives & weeds; perennial weeds; & perennial native seedlings (1mx1m quadrats) 3. Estimates of litter, fallen woody debris & bare ground 4. Cover of entirely dead plants 5. Vegetation condition & structure 6. Presence/absence of annuals	• Determine the effect of perennial veldt grass control on floristics, vegetation condition & structure • Help direct weed management in the future • Create a species list for the bushland area • Assess vegetation condition & structure over time
	Spring 2014 (10mx10m)	Fire area	As above (1-6), but also recording fire response strategy (resprouting or seeding)	• Determine the effect of fire on floristics, vegetation condition & structure
Tree seedling count	Spring yearly	All 31 veldt monitoring quadrats	10mx10m quadrats 7. Count of tree seedlings	• Determine the effect of perennial veldt grass control on tree seedlings
	Spring yearly	Fire area	As above (7)	• Determine the effect of fire on tree regeneration from seed
Veldt & other major weeds survey	Spring alternate years	All 31 veldt monitoring quadrats	10mx10m quadrats 8. Count & cover of perennial veldt 9. Presence/absence & cover of all other major weeds (annuals & perennials) 10. Cover of total weeds	• Determine the effect of perennial veldt grass control on veldt & other major weeds • Help direct weed management
Post-fire monitoring	Monthly 2014 Quarterly 2015	Fire area	10mx10m quadrats 11. Count of adult, sapling & seedling plants for canopy species &, if resprouting, record if base or canopy 12. Presence/absence of all understorey annual & perennial natives & weeds 13. Fire response strategy employed (i.e. resprout or seedling) for every understorey species 14. Flowering/seeding 15. Cover of perennial veldt grass 16. Cover of all other major weeds (annuals & perennials) 17. Photomonitoring of certain selected plants & scenes/views post-fire	• Record the recovery or return of native & weed species after fire • Compare native & weed species diversity before & after fire • Record fire response strategy (resprouting/reseeding) for native & weed species • Record plant reproduction (flowering/seeding) after fire • Record changes in plant diversity
Post-fire tree mortality	August 2014 June 2015	Fire area	25mx25m quadrats 18. count of adults & saplings of every individual (alive or dead) 19. lifestage 20. resprout strategy (base or trunk or canopy) & health 21. diameter at breast height	• Determine tree mortality rate in bushland that has been burnt • Correlate success of recovery from fire with species, resprout strategy & age (via diameter)
Photomonitoring	Autumn, Spring yearly	All 31 veldt monitoring quadrats	22. Eight photos are taken, looking into the quadrat from each corner & centre of each side (10mx10m quadrats) 23. Photos are taken looking downward & upward at the centre of each of nine 1mx1m quadrats in 10mx10m quadrats (1mx1m quadrats)	• Provide a visual representation of the results of the perennial veldt spraying programme • Automatically estimate cover using computer algorithms
	Monthly 2014 Quarterly 2015	Fire area	As above (22-23)	• Provide a visual representation of the recovery/return of native & weed species after fire

Appendix 2. Species of Native Plants Present in Restoration Areas

Plants present in revegetated sites the third year after establishment (2014). Species are from the topsoil seed bank, local spread, or from inclusion in planting and seeding lists (total 150).

Species	Topsoil	Direct Seeded	Planted 2012/13	Planted 2014	Local Opportunistic	Dampland only	First flowering
Acacia huegelii	1						
Acacia pulchella	1						2014
Acacia saligna	1			1	1		
Acacia stenoptera	1						2014
Adenanthos cygnorum	1						
Alexgeorgea nitens?	1						
Allocasuarina fraseriana		1	1	1			
Allocasuarina humilis		1	1	1			
Amphipogon turbinatus	1	1		1			
Anigozanthos humilis	1	1					2013
Anigozanthos manglesii	1	1	1	1			2012
Aotus procumbens	1			1	1		2013
Arnocrinum preissii	1						2013
Astroloma sp.	1						
Austrostipa compressa	1	1			1		2012
Babingtonia camphorosmae		1					2104
Banksia attenuata	rare	1	1	1			
Banksia ilicifolia		1	1	1			
Banksia menziesii		1	1	1			
Beaufortia elegans				1		1	
Boronia ramosa	1						2013
Bossiaea eriocarpa	1	1					
Brachyloma preissii	1			1			2014
Burchardia congesta	1	1					2014
Caladenia flava	1						2014
Calandrinia corrigioloides	1						2013
Calandrinia granulifera	1						2013
Calothamnus lateralis				1		1	
Calytrix fraseri				1			2014
Cartonema philydroides	1				1		2012
Cassytha sp.	1				1		
Centrolepis drummondiana	1						2012
Centrolepis inconspicua	1						2013
Chamaescilla corymbosa	1						2013
Comesperma calymega	1						2013
Conostylis aculeata		1	1	1			
Conostylis juncea	1						
Conostylis setigera	1			1			2014
Corymbia calophylla				1		1	
Corynotheca micrantha	1						
Crassula colorata (2 subsp.)	1						2012
Croninia kingiana	1						2014
Dampiera linearis	1		1				2013
Dasypogon bromeliifolius	1	1		1			2013
Daucus glochidiatus	1						2014
Daviesia nudiflora	1						
Daviesia physodes	1						
Daviesia triflora	1						
Desmocladus flexuosus	1			1			
Dichopogon capillipes				1			
Diuris corymbosa	1						2014
Drosera erythrorhiza	1						
Drosera glanduligera	1						2012
Drosera macrantha (climbing)	1						2013
Drosera paleacea	1						
Epilobium hirtigerum					1		2013

Species	Topsoil	Direct Seeded	Planted 2012/13	Planted 2014	Local Opportunistic	Dampland only	First flowering
Eremaea asterocarpa		1	1	1			2013
Eremaea pauciflora	1	1	1	1			
Eucalyptus marginata		1	1	1			
Eucalyptus rudis				1	1	1	
Eucalyptus todtiana		1	1	1			
Exocarpos sparteus					1		
Gastrolobium capitatum	1	1					2014
Gnephosis angianthoides	1						2012
Gompholobium tomentosum	1	1		1			2013
Gonocarpus pithyoides	1						2013
Grevillea vestita	1						
Haemodorum spicatum	1	1					2013
Hakea prostrata		1					
Hardenbergia comptoniana	1				1		
Hemiandra pungens	1				1		2013
Hensmania turbinata	1						2014
Hibbertia huegelii	1	1	1	1			2013
Hibbertia hypericoides	1			1			2013
Hibbertia racemosa				1			
Hibbertia subvaginata	1		1	1			2012
Homalosciadium homalocarpum	1						2012
Hovea trisperma	1						2013
Hyalospermum cotula	1						2013
Hypocalymma angustifolium	1	1		1			
Hypolaena exsulca	1						
Jacksonia furcellata	1	1	1	1	1		2014
Jacksonia sericea	1						2014
Jacksonia sternbergiana	1						
Juncus pallidus					1		
Kennedia prostrata	1			1			2013
Kunzea glabrescens	1		1	1	1		
Laxmannia ramosa	1						2013
Laxmannia squarrosa	1						2013
Lechenaultia floribunda	1		1		1		2013
Lepidosperma sp.				1			2014
Lepidosperma squamatum	1		1	1			2013
Leucopogon conostephioides	1						2014
Levenhookia stipitata	1						2012
Lobelia tenuior	1				1		2012
Lomandra caespitosa	1			1			2014
Lomandra hermaphrodita	1			1			
Lomandra nigricans				1			2014
Lomandra preissii				1			
Lomandra suaveolens				1			
Lyginia barbata/imberbis	1			1			
Macarthuria australis		1			1		2012
Macarthuria apetala	1						2014
Macrozamia riedlei		1					
Melaleuca preissiana				1		1	
Melaleuca rhaphiophylla				1		1	
Melaleuca seriata		1	1	1			2013
Melaleuca teretifolia				1		1	
Melaleuca thymoides	1	1	1	1			
Melaleuca viminea				1		1	
Microtis media					1		2013
Millotia tenuifolia	1						
Nuytsia floribunda		1	1	1			
Orthrosanthus laxus				1			
Patersonia occidentalis	1	1					2013
Persoonia saccata	1						

Species	Topsoil	Direct Seeded	Planted 2012/13	Planted 2014	Local Opportunistic	Dampland only	First flowering
Petrophile linearis		1	1	1			
Phlebocarya ciliata	1		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/moorkatta	1						2012
Quinetia urvillei	1						2012
Regelia ciliata				1		1	
Regelia inops				1			
Rhodanthe citrina	1						2012
Scaevola repens	1						
Schoenus curvifolius				1			
Schoenus efoliatus				1			
Scholtzia involucrata		1	1	1			
Senecio pinnatifolius					1		2013
Shrub 1	1						
Shrub 2	1						
Siloxerus humifusus	1						2012
Sowerbaea laxiflora	1						2014
Stirlingia latifolia	1	1		1			
Stylidium brunonianum	1						2013
Stylidium piliferum	1						2013
Stylidium repens	1						
Synaphea spinulosa	1						2014
Thysanotus arbuscula	1						2012
Thysanotus sp. climbing	1						
Thysanotus thyrsoideus	1						2013
Trachymene pilosa	1						2012
Wahlenbergia preissii	1						2013
Xanthorrhoea preissii		1	1	1			
Xanthosia atkinsoniana	1						2013
TOTAL	**105**	**34**	**25**	**59**	**20**		**82**

Appendix 3. Cost Estimates for Banksia Woodland Restoration

A. Cost per ha 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 per 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 no planting cost)	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 > 1 year old. 2 Effective restoration often requires both seeding and tubestock (and topsoil if available). 3 It usually takes 3 - 4 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 ha and 7000 understory plants per ha. 6 Seed cost is also included in previous columns. 7 No monitoring, management, or reporting costs are included. 8 Total costs per ha are not additive as areas with direct seeding or topsoil required less tubestock.