Volunteer removal of woody weeds from the Australian National Botanic Gardens and its annexes, February 2013 – June 2014

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Executive Summary

From February 2013 to June 2014 the Friends of Black Mountain carried out a program of woody weed removal from the Australian National Botanic Gardens and its two annexes. These areas adjoin Black Mountain Reserve which has high conservation value, especially for the suite of rare plants that occur there.

Weeding outcomes

- The equivalent of 58 days of weeding was carried out over 14 sessions by 32 volunteers from two Friends groups and 15 from GE Money.
- Approximately 4200 woody weed plants from 115-126 species and 54-58 genera were removed or cut and poisoned; 87% were native plants of species not indigenous to Black Mountain (i.e. non-local native species) and the remainder plants of exotic species introduced to Australia.
- Fifteen species each had more than 50 plants removed; 13 of these abundant taxa were non-local native species.
- Of the 115-126 species removed, 89-96 (76-77%) were non-local native species, and the remainder exotic.
- Of the 54-58 genera represented, 31 (53-57%) were native genera.

Of the native woody weed species removed:

- 91% were derived solely from plants cultivated within the Gardens.
- *Acacia* and *Grevillea* were 'more weedy' than other native genera, with 35-39 species of Acacia and 17-20 species of *Grevillea* removed.
- Of the 13 abundant native species, 11 were derived solely, and two in part, from plantings within the Gardens.
- Eight of the abundant native taxa were species of *Acacia*.

Does ANBG have a native woody weed problem?

Just over three times more native weed species were removed as exotic species, and almost seven times more native weed plants taken out than individuals of exotic species. This suggests that cultivated native species in the Gardens are a potential weed 'problem'. The genus *Acacia* appeared to present a specific weed 'problem': the majority of the abundant species were acacias, and it had the largest number of species removed.

Further analysis of data from the weeding program showed that:

- Two of the abundant native species, *Acacia baileyana* and *A. decurrens*, are widespread invasive weeds in the ACT.
- The other 11 abundant native species (*Billardiera heterophylla*, *Dodonaea triangularis*, *Grevillea* aff. *rosmarinifolia*, *Acacia extensa*, *A. howittii*, *A. longifolia*, *A. melanoxylon*, *A. stricta*, *A. viscidula*, *Kunzea flavescens* and *Pittosporum undulatum*) also appear to warrant being treated as potentially invasive. They comprised 13% of all native woody weed species removed.
- Of the native weed species derived solely from plantings within the Gardens, about 68% had only 1-10 plants removed; their small numbers suggest that currently they pose no significant invasive risk.

Whether or not a species is likely to become invasive is affected by the pressure of introduction, the inherited attributes of the species, and the suitability of the local environment. An examination of

ANBG planting records and other data for the abundant species and all *Acacia* species removed during the weeding program showed the following.

Pressure of introduction

- The invasive/potentially invasive native species removed all had a high pressure of introduction (multiple plantings over multiple sections of the Gardens), but the number of plantings and the number of sections planted in was not a good guide to relative invasiveness.
- Proximity to natural areas (i.e. being planted in beds adjacent to natural bushland) probably facilitated naturalisation but was not a precursor for all the species that became invasive.
- At least 529 *Acacia* species have been planted in the Gardens, but only 7% of them were removed in the weeding program.
- *Acacia* species with >10 plantings or being planted in 7 or more sections were more likely to naturalise, but the number of plantings and number of sections planted in was not a good indicator of invasiveness.
- About 72% of all *Acacia* species planted in the Gardens have had 1-10 plantings, i.e. most planted *Acacia* species probably have a low invasive potential.

Inherent attributes and Environmental suitability

Many species removed in the weeding program had attributes typical of naturalised invasive species.

- Four of the abundant species were relatively long-lived trees or tall shrubs with prolific seed production.
- Of the 13 abundant native species removed, one has wind-dispersed seed and the seeds or fruit of the other 12 species are, or are probably, dispersed by birds or ants.
- The majority of weed species removed occur naturally in New South Wales and are relatively widespread there. They include 36 of the 43 weeds identified to species level, 9 of the 13 abundant species, and 23 of the 26 weedy *Acacia* species.

If extrapolated to the rest of the Gardens, the above analyses suggest that:

- While many woody species planted in the Gardens have naturalised, they are a small proportion of all species planted.
- The majority of woody species planted have a low naturalisation potential.

The Gardens therefore should not currently be viewed as a major 'woody weed problem'. However a small number of species have naturalised, and are or have the potential to be invasive in adjacent areas of Black Mountain Reserve, and thus warrant management intervention.

Management implications

Minimising the likelihood of native species from the Gardens invading the Reserve should continue to rely on a combination of buffers and vigilance, including one or more of the following.

- Continuing to retain the natural sections of the Gardens adjacent to the boundary fence as buffer areas where no new plantings are made and extant cultivated plants are considered for removal.
- Implementing an ongoing, regular weed removal program in the buffer and nearby natural areas of the Gardens, targeting both native and exotic weed species.
- Making strategic decisions about if and where to retain known weedy species in cultivated sections of the Gardens, and whether and where to add new plantings of species that might become invasive.

1. Background

Black Mountain Reserve (the Reserve) is part of Canberra Nature Park and conserves high quality native vegetation, predominantly in the 'Red Stringybark – Scribbly Gum – *Rytidosperma pallidum* tall grass-shrub dry sclerophyll open forest on loamy ridges' association (Armstrong et al. 2013). It stands out for its very high diversity of rare plant species and "supports many plant species with disjunct locations within the ACT; … is the only known location within the ACT of at least eight plant species and is an ACT stronghold for many other rare plants" (Mulvaney 2014).

The Friends of Black Mountain (FoBM) commenced a weeding program in the Reserve in November 2012. In early 2013 weeding effort was focused on the removal of woody weeds from the Reserve, encompassing species introduced to Australia (exotic species) as well as native Australian species not indigenous to Black Mountain. A 1969 list of vascular plants recorded on Black Mountain and adjacent areas (Gray & McKee 1969) was used to determine what species are indigenous to the area and which should be considered weeds.

The Australian National Botanic Gardens (ANBG or the Gardens) adjoins the Reserve on the eastern slopes of Black Mountain. In January 2013 FoBM approached the ANBG Manager to remove woody weeds from those sections of the Gardens adjacent to the Reserve. The purpose was to remove species known to be invasive in the Reserve (such as *Billardiera heterophylla* (Sollya) and *Acacia baileyana* (Cootamundra Wattle)) and those that had the potential to invade it.

2. Methods

2.1 Identifying target areas for the weeding program

Initially FoBM targeted sections with relatively undisturbed natural vegetation (natural sections) along the southern and western boundary of the Gardens. It later sought approval to work in the northern part of the Southern Annex and throughout the Northern Annex. The former is highly disturbed and contained numerous woody weed species known to be invasive in the Reserve. The latter contains relatively undisturbed natural vegetation in its upper half, but an FoBM member who is a botanist (here-after referred to as the FoBM botanist) was aware that the disturbed lower half contained many shrubs that had naturalised from cultivated plants in adjacent sections of the Gardens.

FoBM visually identified relevant natural sections within the Gardens using the ANBG section map[1]. For each of these, and in the Northern Annex, FoBM then checked what species, if any, had been planted there and how many plantings remained alive (using the ANBG Living Collection database[2]), and whether the area was still actively maintained as a cultivated section (through discussions with ANBG staff). FoBM sought additional permission to include cultivated sections adjacent to the Northern Annex, as it was evident they also contained numerous naturalised shrubs. The areas targeted, covering approximately 17 ha, are shown in Figure 1.

2.2 Pre-weeding survey

Sections in the central and southern areas of the Gardens (sections 58, 61, 156 and 185-88) contained relatively few extant plantings. These plantings were either species indigenous to Black Mountain or non-indigenous native species that would be easy to identify and avoid[3]. Prior to each weeding session, the FoBM botanist, who had a good knowledge both of the Black Mountain flora and of ANBG plantings, systematically walked through the targeted section/s and compiled a woody

[1] http://www.anbg.gov.au/gardens/living/ANBG_section_map/index.html
[2] http://www.anbg.gov.au/cgi-bin/stock
[3] Cultivated plants can be confirmed by the presence of a metal propagation tag on them.

weed ‘hit list’. Training needs for volunteer weeders to visually identify the weedy species *in situ* were then determined.

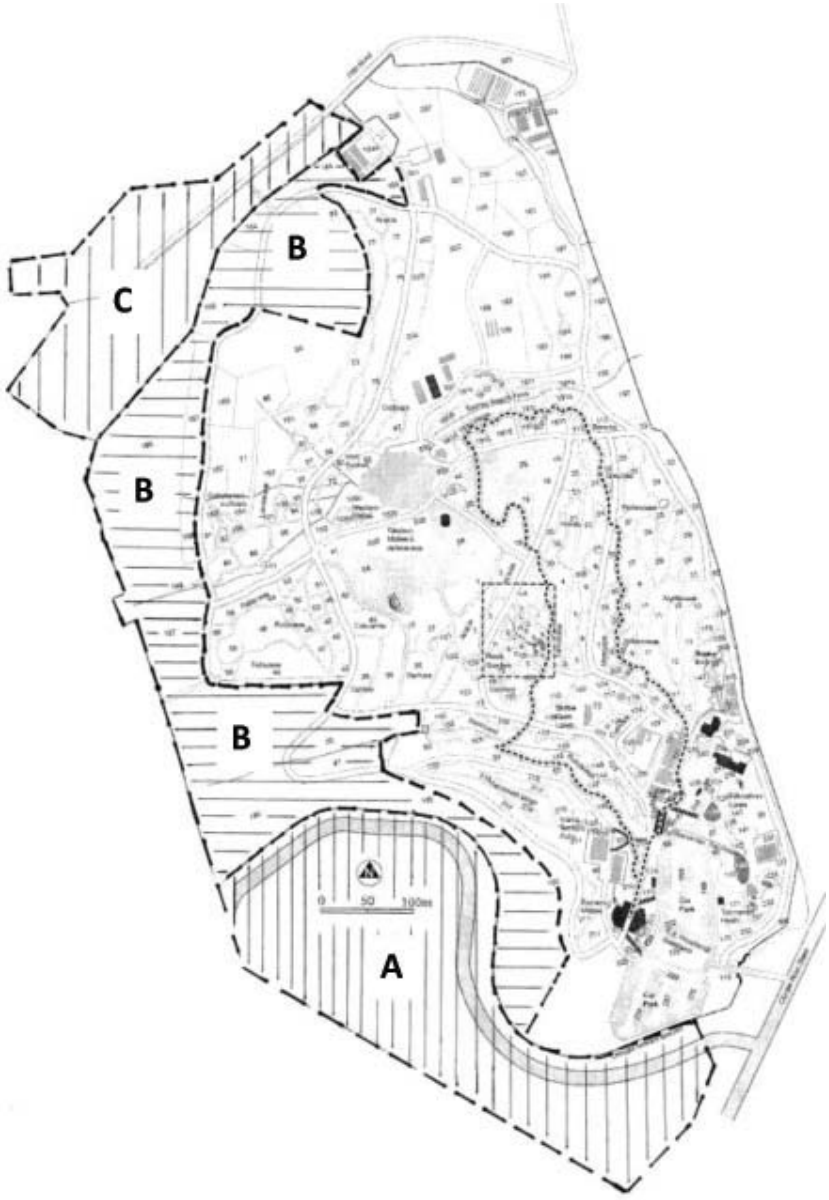

Figure 1. Map of weeding area. A = Southern Annex, B = ANBG, C = Northern Annex

Sections with large numbers of extant cultivated plants (the northern ends of sections 167 and 188 plus sections 89, 93, 164-66 and 184) were inspected by ANBG staff with the FoBM botanist prior to weeding. The ANBG staff decided whether any native non-indigenous plants lacking a propagation number should be retained or removed. All plants designated for removal were marked with pink or orange plastic tape. The FoBM botanist made herbarium specimens of the more abundant woody weed species to allow their correct identification and to provide a permanent record of their occurrence.

Prior to weeding in the Southern Annex, the FoBM botanist walked through the targeted area and compiled a list of all woody weed species to be removed and their approximate location. In the Northern Annex, the botanist walked throughout the area and marked with pink or orange plastic tape all plants to be removed.

A summary of the areas targeted for weeding and the method used by volunteers to identify plants for removal is provided in Table 1.

Table 1. Areas targeted for weeding and weed identification method used by volunteers.

Weeding area (section number or Annex)	Any plantings recorded in ANBG database?	Extant plantings recorded in ANBG database?	Section maintained as cultivated area?	Weed identification (ID) method used
58	Yes	No	No	On spot visual ID
61	Yes	No	No	On spot visual ID
89	Yes	No	No	Plants marked for removal
93	Yes	Yes	No	Plants marked for removal
156	Yes	Yes	No	On spot visual ID
164	Yes	Yes	Yes (part only)	Plants marked for removal
165	Yes	Yes	Yes	Plants marked for removal
166	Yes	Yes	No	Plants marked for removal
167	Yes	Yes	No	On spot visual ID; plants marked for removal in northern end of section
184	Yes	Yes	Yes	Plants marked for removal
185	Yes	Yes	No	On spot visual ID
186	Yes	No	No	On spot visual ID
187	Yes	Yes	No	On spot visual ID
188	Yes	No	No	On spot visual ID; plants marked for removal in northern end of section
Southern Annex	No	-	-	On spot visual ID
Northern Annex	No	-	-	Plants marked for removal

2.3 Weeding sessions

Regular weeding sessions were scheduled for the first Saturday morning of each month. The 'weeders' were mostly volunteers from the Friends of Black Mountain and/or Friends of the Australian National Botanic Gardens. Volunteers from GE Money's Canberra office were also involved once in a separate weeding session. Except for one session in the Southern Annex, each session was supervised by the FoBM botanist who had carried out the pre-weeding survey.

Where the weeding relied on on-the-spot visual identification of plants, the weeders were given initial training to identify the target species (mostly Sollya, Cootamundra Wattle and *Acacia melanoxylon* (Blackwood)) and to distinguish them from any similar native species. Where the weeds had been marked with plastic tape, no training was required. At least one weeder with relevant botanical expertise was always present to decide whether to remove or leave unmarked plants suspected of being a weed. When there was doubt or uncertainty, plants were first checked for an ANBG propagation tag to ensure cultivated plants were not removed accidentally.

The weeders mostly worked in pairs, and those with no botanical knowledge were initially paired with someone familiar with the weed species. The weeders systematically moved through each target area and either pulled plants out of the ground (with minimal soil disturbance) or cut the stems low to the ground and poisoned them with Roundup using weeding wands or similar (cut and dab technique). Plants destroyed were left *in situ* to rot unless their biomass was so great that removal was warranted. In the latter case, the weeders created piles of cut plants on the edge of the

roads for ANBG staff to remove and/or chip at a later stage. Sollya plants with ripe fruit were piled on the roadside for removal by ANBG staff or the fruit-laden twigs put in plastic bags for off-site disposal. Plants too large for the weeders' equipment (i.e. that required the use of chainsaws) were left for later removal by ANBG staff.

During morning tea and at the end of each session, each weeder estimated the number of plants of each species that s/he had removed (for unmarked plants) or returned the plastic tapes for later counting. No detailed record was kept of herbaceous weeds (such as thistles, fleabanes etc) removed opportunistically.

2.4 Post weeding

After each weeding session, the FoBM botanist re-walked the target area to mark any missed weeds (for removal in the following session), rearrange cut weed biomass to minimise native vegetation being smothered, and to identify other subsequent action required. A written report was provided to ANBG management, outlining the weeding effort, the number of plants removed, the species removed and any follow-up actions for ANBG gardeners.

3. Outcomes of weeding activities

3.1 Weeding effort

The equivalent of 58 days of weeding was done (Table 2) by a total of 32 individuals from the two Friends groups over 13 sessions and 15 GE Money volunteers for one session. An average of nine people from the Friends (range 6-15) volunteered per session. One session was cancelled because no supervisor was available, and three sessions because of wet weather.

Table 2. Summary of weeding effort by Friends of Black Mountain and Friends of ANBG (2 Feb 2013 to 25 May 2014) and GE Money volunteers (5 June 2014).

Date	Area targeted: ANBG section numbers or Annex	Number of people	Time in field (hours)	Total effort (hrs) (people x time)[1]
2 Feb. 2013	Southern Annex (road verge between ANBG Fence & BM Drive)	9	c. 2	20.0
2 Mar. 2013	185	15	c. 3	45.25
6 Apr. 2013	185, 186	9	c. 3	30.5
4 May 2013	186, 187	7	c. 3	27.0
1 June 2013	187, 188, 156, 167	11	c. 1.5	30.25
6 July 2013	58, 187, 188, 156, 167, 89, 93, 166	11	c. 3	37.0
3 Aug. 2013	Southern Annex	6	c. 3	21.5
7 Sep. 2013	Southern Annex	6	c. 3	13.25
2 Nov. 2013	Southern Annex	6	c. 3	17.5
7 Dec. 2013	89, 93, 164, 166, 167, 188	12	c. 3.5	47.5
4 Jan. 2014	89, 93, 164, 165, 166, 167, 184	8	c. 3.5	37.5
1 Feb. 2014	89, 165, 184, ANBG Northern Annex	12	c. 2.0	31.0
25 May 2014	ANBG Northern Annex	8	c. 3.0	30.25
5 June 2014	Southern Annex, inc. road verge between ANBG Fence & BM Drive	15	c. 2.0	30.0
			Total	418.5 (58 days)

1. Includes pre-weeding surveys and marking plants with plastic tape, topping up weeding wands, cleaning tools afterwards and post-weeding checks.

3.2 Woody weed species removed

All species removed from the Gardens and the two annexes are listed in Appendix 1 (native species) and Appendix 2 (exotic species), and the data summarised in Table 3. The plants removed were from 115-126 species[4] in 54-58 genera[5] (Table 3). They included 26-30 exotic species and 89-96 native species not indigenous to Black Mountain. The latter represented 76-77% of all species removed, and 53-57% of all genera. About 91% of the non-indigenous native species removed were derived solely from plants cultivated within the Gardens.

In the Gardens, almost 70% of all genera and 85% of all species removed were derived from plants cultivated there, whereas in the Northern Annex, only 43% of genera and 58% of species removed were derived from ANBG plantings. The Northern Annex also contained three non-indigenous native species of *Grevillea* that had been used in road landscaping and subsequently naturalised. In the Southern Annex, further away from cultivated sections of the Gardens, only 28% of genera and 33% of species removed originated from ANBG plantings.

Native woody weed species widespread in Canberra but not indigenous to Black Mountain comprised a higher proportion of all genera and species removed in the more disturbed Southern Annex (17% of genera and species) compared with the Gardens (2% of genera; 3% of species) and Northern Annex (5% of genera, 3% of species). The exotic species removed were less common in the Gardens (about 33% of genera and 15% of species) compared with the southern and northern annexes (61% of genera, 50% of species and 57% of genera, 32% of species respectively).

Table 3. Number of woody weed genera and species removed.

Plant type	Number of taxa							
	S Annex		ANBG		N Annex		Whole area	
	Genera	Species	Genera	Species	Genera	Species	Genera	Species
Native	**7**	**12**	**29**	**78-85**	**9**	**25-27**	**31**	**89-96**
• ex-ANBG	5	8	29	75-82	9	21-23	29	81-88
• Widespread	3	4	1	3	1	1	3	5
• Landscape	-	-	-	-	1	3	1	3
Exotic	**11**	**12**	**12-16**	**12-16**	**12**	**12**	**23-27**	**26-30**
Total	**18**	**24**	**41-45**	**89-101**	**21**	**37-39**	**54-58**	**115-126**

Of the 31 genera of native woody weeds, *Acacia* and *Grevillea* contributed the largest number of species and these were more than three times more prevalent than species in the next largest genus, *Persoonia* (Table 4). *Acacia* and *Grevillea* thus appeared to be 'more weedy' than other native genera. Four genera were each represented by two species, and the remaining 24 (see Appendix 1) by a single species each.

[4] At least three of the taxa removed were cultivars, but they are treated as 'species' in this report.

[5] The uncertainty in exact numbers of species and genera was because it was not possible to match unidentified species removed from different sections during different weeding sessions.

Table 4. Number of woody weed species removed in each native genus.

Genus	Species	
	Number	**%**
Acacia	35-39	39-40
Grevillea	17-20	19-21
Persoonia	5	5-6
Dodonaea	2	2
Melaleuca	2	2
Pittosporum	2	2
Solanum	2	2
24 other genera	1 species/genus	1%/genus
Total	**90-97**	**100**

3.3 Number of woody weed plants removed

The total number of plants removed for each species is shown in appendices 1 and 2, and the data summarised in Table 5. Approximately 4200 plants were removed, about 650 from the Southern Annex, almost 2900 from the Gardens and almost 660 from the Northern Annex. About 87% of the plants were native Australian species not indigenous to Black Mountain, of which 75% were derived from plants cultivated in the Gardens. Only 13% of plants removed were exotic species.

Within the Gardens, 72% of the plants removed were derived from ANBG plantings located in adjacent or other garden beds. Almost 24% of all plants removed from the Gardens were widespread native woody weeds, and only 4.5% were exotic species.

In the Southern Annex 56.5% of plants removed were native species, 75% of which were sourced from ANBG plantings; 43.5% of plants removed were exotic species. In the Northern Annex 79% of plants removed were native species, 72% of which were sourced from ANBG plantings, and 21% were exotic plants.

Table 5. Number of woody weed plants removed.

Plant type	Number of plants			
	S Annex	**ANBG**	**N Annex**	**Whole area**
Native	**368**	**2768**	**518**	**3654**
• ex-ANBG	275	2081	373	2729
• Widespread	93	687	145	925
Exotic	**283**	**131**	**137**	**551**
Total	**651**	**2899**	**655**	**4205**

The relative abundance of weed plants removed for species is shown in Table 6. About 60% of exotic species, and 68% of native species derived solely from ANBG plantings, had only 1-10 plants removed, i.e. the majority of species were uncommon. About 7% of exotic species, and 13% of native species derived solely from ANBG plantings, had more than 50 plants removed; these are termed ‘abundant species’ in the following sections.

Table 6. Relative abundance of plants removed (measured by plant removal classes) by number of species meeting each class.

No. of plants class	Number of species											
	Native, derived solely from ANBG plantings				Native, widespread/used for landscaping outside ANBG				Exotic			
	S Annex	ANBG	N Annex	Whole area[1]	S Annex	ANBG	N Annex	Whole area[1]	S Annex	ANBG	N Annex	Whole area[1]
1-10	5	57-64	16	57-60	3			2	10	6-10	6	15-19
11-20		5	3	7			2	2	1	4	4	6
21-30		2		2						1	1	2
31-40		1	1	1		1	1	2		1		
41-50	2	3		1							1	1
51-60		1										
61-70		2		2								1
71-80		1		2			1					
81-90					1							
91-100						1		1				
101-150		1	2	3								
151-200	1	1		2								
201-250									1			1
301-350		1		1								
551-600						1						
651-700		1										
701-750								1				
850-900				1								
	Total species			**82-89**	**Total species**			**8**	**Total species**			**26-30**

1. Note: the number of species in the whole area (i.e. S Annex, ANBG and N Annex) is not the sum of the figures in the preceding columns for each row, as the combined numbers of plants removed for a species often puts the total in a higher class.

3.4 Abundant woody weed species

Woody weed taxa with more than 50 plants removed during the program, i.e. abundant species, are listed in Table 7. They comprised two exotic and 13 native species. Of the latter, 11 were derived solely from Gardens' plantings and two, both widespread weed species, were probably derived in part from Gardens' plantings (see section 4.2.1). Eight of the 13 abundant native taxa were species of *Acacia*.

Billardiera heterophylla (Sollya) and *Acacia baileyana* (Cootamundra Wattle) were the most prevalent species, with 877 and 720 plants removed (respectively). Cootamundra Wattle is a widespread native weed in Australia (Table 7) and was reported to be locally common on Black Mountain as early as 1969 (Gray & McKee 1969). It is one of the most significant woody weeds in the ACT (Berry & Mulvaney 1995). Sollya is also known to be a widespread native weed (Table 7 and Berry & Mulvaney 1995) although the plants removed during the weeding program are most likely to have originated from plants cultivated in the Gardens. Both species are highly invasive in the ACT (Berry & Mulvaney 1995) and have been widely cultivated in Canberra.

Of the other 11 native species in Table 7, 10 were derived solely from ANBG plantings. Seven are known to be naturalised in other states, and nine are included in the ANBG weed list. *Acacia decurrens* and *Pittosporum undulatum* are considered to be highly invasive in the ACT (Berry &

Mulvaney 1995), while *Grevillea* aff. *rosmarinifolia* is also likely to be, given its parent is highly invasive there (Berry & Mulvaney 1995). Five species derived solely from ANBG plantings and on the ANBG weed list (*Acacia howittii*, *A. longifolia*, *A. melanoxylon*, *Billardiera heterophylla* and *Grevillea* aff. *rosmarinifolia*) have been recorded on the eastern slopes of Black Mountain in the Reserve, as have the two widespread native species, *Acacia baileyana* and *A. decurrens* (Purdie 2009). No records have been located of *Acacia stricta* and *Dodonaea triangularis* being naturalised and potentially invasive elsewhere in Australia, although the former species is invasive overseas (Richardson et al. 2011).

Table 7. Abundant woody weed species.

Species	Number of plants removed				Recorded as naturalised[1]	ANBG weed list[2]
	S Annex	ANBG	N Annex	Whole area		
Native species ex-ANBG						
Billardiera heterophylla[3]	180	697		877	NSW, ACT, Tas, SA	R1
Pittosporum undulatum		305	1	306	NSW, Vic, Tas, SA, WA	R1
Kunzea flavescens		165	1	166	-	R2
Dodonaea triangularis		50	105	155	-	-
Grevillea aff. *rosmarinifolia*[3]			140	140	Qld, ACT, SA	R2
Acacia viscidula		102	31	133	-	R3
Acacia melanoxylon[3]	41	68	1	110	WA	R3
Acacia howittii[3]		61	15	76	ACT (d), Vic, SA?	R2
Acacia extensa		75		75	Vic	R3
Acacia stricta		49	20	69	-	-
Acacia longifolia[3]		59	2	61	ACT (f), Vic, SA, WA	R1
Widespread native species						
Acacia baileyana[3]	85	560	75	720	Qld, NSW, ACT, Vic, SA, WA	R1
Acacia decurrens[3]		93		93	Qld, ACT, Vic, Tas, SA, WA	R1
Exotic species						
Fraxinus angustifolia[3]	230		13	243	Qld (d), NSW, ACT, Vic, Tas, SA, WA	N/A
Rubus sp. (Blackberry)[3] (probably *R. anglocandicans*)	Yes	34	28	62	Qld, NSW, ACT, Vic, Tas, SA, WA	N/A

1. From the Australian Plant Census (http://www.anbg.gov.au/cgi-bin/apclist). d = doubtfully naturalised, i.e. species with scattered small populations which may or may not persist in the longer term; f = formerly naturalised, i.e. species previously recorded from the ACT, but for which no collections have been made within the past 30 years.
2. Level of threat to one or more habitats in Southern Australia: R1 = very serious; R2 = serious; R3 = potential (Anon 2007).
3. Species recorded from relatively undisturbed vegetation in Black Mountain Nature Reserve (Purdie 2009).

4. Is ANBG a significant local source of invasive native woody weed species?

The data in Section 3 show that most of the weeds removed were native species, most of which originated solely from Gardens' plantings. The number of native weed species removed was just over three times the number of exotic species, and almost seven times more native weed plants

were removed than exotic plants. This suggests that cultivated native species in ANBG are an actual and potential weed 'problem' for adjacent natural areas in the Gardens and in the Reserve.

Up to 70% of weeds in Australia are known to be derived from plants in both private and public gardens, and they include native Australian shrub species (e.g. Mulvaney 1991; Groves et al. 2005). Weeds can have significant adverse environmental impacts when they invade native vegetation (Groves et al. 2005). The time span between introduction and naturalisation of weedy species in Australia has ranged from 20-300 years or more (Groves et al. 2005). While many naturalised plants never become invasive (i.e. significantly increase their population size and become dominant in the vegetation), it may take an extended period of time after naturalisation for this to occur (Groves 1999). It is thus important to assess whether the results described above might be seen as a problem for ANBG.

Mulvaney (1991) defined a species as being invasive in south-eastern Australia if it dominated a 20 m x 20 m area of bushland, while in the ACT Berry and Mulvaney (1995) defined it as dominance over an area at least 30 m x 30 m. Berry and Mulvaney (1995) outlined three key factors that affect whether a species is likely to become an environmental weed (i.e. invasive):

- The pressure of introduction, including the timescale, extent and quantity of introduction (Mulvaney 2001).
- The inherited attributes of the species, including reproductive method and dispersal mechanism.
- The suitability of the local environment for the species.

These factors are used below as a framework for further analysis of the extent to which the Gardens might (or might not) have a 'woody weed problem'.

4.1 Should any of the native species removed be considered invasive in Canberra?

Only one weed species removed during the ANBG weeding program, *Kunzea flavescens*, would have met the invasive definition of being dominant over a 20 m x 20 m natural area[6]. *Acacia baileyana*, *A. decurrens* and *Billardieria heterophylla* would have approached this definition in some areas (and undoubtedly would meet it if left to spread naturally). *Acacia extensa*, *A. howittii*, *A. longifolia*, *A. melanoxylon*, *A. stricta*, *A. viscidula*, *Dodonaea triangularis* and *Grevillea* aff. *rosmarinifolia* were each co-dominant in various areas smaller than 20 m x 20 m, but probably could have met the definition over time if left unchecked. Although *Pittosporum undulatum* was the third most abundant native species removed, most of the plants were seedlings or small saplings scattered through many sections. Left unchecked however, it also would have the potential to meet the invasive definition based on the large size of some of the mature plants removed.

As noted earlier, *Acacia baileyana* and *A. decurrens* are invasive species widespread in the Canberra area and the plants removed were probably sourced from parents both within and outside the Gardens. The other 11 species in the paragraph above were derived solely from ANBG plantings, and their abundance warrants them also being treated as potentially invasive. Of these, only *Acacia stricta* and *Dodonaea triangularis* are not on the ANBG weed list (Anon 2007); the other nine are categorised as a very serious, serious or potential weed risk in southern Australia on that list. These 13 species represent about 14% of the native woody weed species removed.

The finding that 68% of native species derived solely from plantings within the Gardens had 10 or fewer plants removed (Section 3.3) suggests that although these species had naturalised, currently they are not a high invasive risk on Black Mountain. Twelve of the species, viz. *Acacia binervata, A.*

[6] The smaller of the two areas (20 m x 20 m cf 30 m x 30m) has been chosen for use in this report because, in the context of bushland remnants in urban Canberra, this size is more relevant than the larger 30 m x 30 m area.

boormanii, A. elata, *A. floribunda*, *A. iteaphylla*, *A. terminalis*, *Eucalyptus globulus*, *Grevillea juniperina*, *Grevillea rosmarinifolia*, *Hibbertia scandens*, *Kennedia rubicunda* and *Melicytus dentata* (Appendix 1), are included on the ANBG weed list (Anon 2007). Their lack of current invasiveness in bushland areas of the Gardens does not however mean they warrant removal from the list, given their known weediness elsewhere or the risk of them being 'sleeper' weed species (Groves 1999).

4.2 Pressure of introduction: quantity and proximity The pressure of introduction is a measure of the extent to which a taxon is introduced to a new location over time and in space, and includes factors such as the number of introductions made, their spatial distribution, and the total number of individuals involved (Mulvaney 2001). The chance of a species naturalising increases with the number of times it is introduced (Mulvaney 2001).

For plants cultivated in the Gardens, the number of introductions and their spatial distribution can be can be gauged approximately from the Living Collection database, by examining the number of planting events (plantings) and the number of sections in which plantings occurred. These data were examined for the abundant native species removed (Table 8), and for all species of *Acacia* removed (Table 9).

4.2.1. Abundant native species*.* Of the species with more than 50 plants removed (Table 8):

- The two *Acacia* species widespread in the Canberra area (*Acacia baileyana* and *A. decurrens*) both had multiple plantings in the Gardens and were planted in many sections, i.e. they demonstrated a high pressure of introduction. This also means the plants removed during the program were probably derived from ANBG plantings as well as from outside sources.
- The number of plantings of the abundant species within the Gardens ranged from 115 and 94 for *Acacia melanoxylon* and *A. baileyana* (respectively), to 16 and 8 for *A. extensa* and *Dodonaea triangularis* (respectively). The number of sections they had been planted in ranged from 66 and 45 for *A. baileyana* and *A. melanoxylon* (respectively) to seven and four for *A. extensa* and *Dodonaea triangularis* (respectively).
- The most abundant native species removed, *Billardiera heterophylla*, had 23 plantings in the Gardens spread over 12 sections, compared with 94 plantings over 66 sections for the second most abundant species, *A. baileyana*.
- The above figures indicate that all the invasive/potentially invasive species removed showed a high pressure of introduction (based on the number and extent of plantings). However the number of plantings and the number of sections planted in was not a good guide to relative invasiveness.

***4.2.2 Weedy* Acacia *species*.** The genus *Acacia* had the largest number (35-39) of woody weed species overall (Appendix 1) and the largest number (8) of abundant species (Table 7 or 8), i.e. it appeared to be 'a weed problem'. Twelve of the species (Table 9) have not been recorded by the national and state herbaria as naturalised in Australia, although two of these are on the ANBG weed list (Anon 2007). The latter includes 25 *Acacia* species, more than twice the number of species listed for all other weedy native genera.

Species of *Acacia* are a known weed problem within Australia and in many countries overseas. The Australian Plant Census[7] shows that 43 of the 1158 species in Australia (4%) are known to be naturalised in one or more States or Territories. Richardson et al. (2011) found that of 386 species deliberately moved outside Australia, 71 (18%) have naturalised (i.e. become weedy) and 23 (6%) have become invasive (i.e. come to dominate the vegetation).

[7] http://www.anbg.gov.au/chah/apc/index.html

Table 8. Number of ANBG plantings of the abundant native woody weed species.

Species	ANBG plantings[1]				No. of plants removed
	No. of plantings[2]	No. of sections planted in	No. of plantings current[3]	No. of accessions[4]	
Billardiera heterophylla	23	12	0	12	877
Acacia baileyana	94	66	9	12	720
Pittosporum undulatum	50	20	30	19	306
Kunzea flavescens	23	18	12	7	166
Dodonaea triangularis	8	4	3	5	155
Grevillea aff. *rosmarinifolia*	194[5]	48[5]	30[5]	101[5]	140
Acacia viscidula	26	17	13	10	133
Acacia melanoxylon	115	45	62	38	110
Acacia decurrens	36	29	10	12	93
Acacia howittii	48	30	14	17	76
Acacia extensa	16	7	3	8	75
Acacia stricta	25	15	0	8	69
Acacia longifolia	26	15	5	17	61

1. From the Living Collection Database http://www.anbg.gov.au/cgi-bin/stock.
2. A single planting may be one or more plants; the number of individuals planted out in each planting event is not retained in the database.
3. A "current" planting means one or more of the plants is still alive.
4. Number of different parent plants used in planting events (a rough measure of the number of genotypes planted). It does not take account of whether multiple plantings for each species were from germinated seed or from cuttings; the former would have greater genetic variability than the latter.
5. These data represent all plantings of *Grevillea rosmarinifolia* in the Gardens and comprise many different cultivars. It is not possible to determine the exact figures for *G.* aff. *rosmarinifolia*.

For the *Acacia* species removed during the weeding program, the planting data (Table 9) showed the following.

- All except *A. sertiformis* had more than 10 ANBG plantings over seven or more sections, suggesting that species with 10 or more plantings, or plantings in multiple sections of the Gardens, are more likely to naturalise.
- Many of the *Acacia* species with fewer than 50 plants removed had more plantings in the Gardens, or were planted in more sections there, than the abundant *Acacia* species. This suggests that, for more than 10 plantings, the number of plantings or the number of sections planted in is not a good guide to whether a naturalised species will become invasive.
- Fourteen of the naturalised *Acacia* species are on the ANBG weed list (Anon 2007). Only one potentially invasive species, *A. stricta*, is not on the list.

An analysis of data on all species of *Acacia* in the Living Collection database showed the following.

- 651 *Acacia* species have been propagated in the Gardens, of which 122 lack sufficient data to know whether they have been planted in cultivated beds.
- 529 species are recorded as having been planted out, only 7% of which were species removed during the weeding program, i.e. the naturalised *Acacia* species represent only a small proportion of all *Acacia* species planted in the Gardens.
- About 72% of all *Acacia* species known to have been planted in the Gardens have had 1-10 plantings (Table 10), i.e. most planted *Acacia* species probably have a low invasive potential.

Table 9. Number of ANBG plantings of *Acacia* species removed as weeds. Abundant species are shaded.

Species	ANBG plantings[1]				No. of plants removed	Recorded as naturalised[5]
	No. of plantings[2]	No. of sections planted in	No. of plantings current[3]	No. of access-ions[4]		
Acacia baileyana[6]	94	66	9	12	720	Qld, NSW, ACT, Vic, SA, WA
Acacia binervata[6]	44	21	8	9	4	-
Acacia boormanii[6]	34	16	22	16	3	ACT
Acacia cardiophylla	31	23	8	13	5	ACT(d)
Acacia covenyi	29	15	10	12	1	-
Acacia cultriformis[6]	57	30	9	32	16	ACT(d)
Acacia decurrens[6]	36	29	10	12	93	Qld, ACT, Vic, Tas, SA, WA
Acacia elata[6]	34	18	9	12	2	ACT(d), Vic, WA(s)
Acacia extensa[6]	16	7	3	8	75	Vic
Acacia falcata	18	11	3	11	9	-
Acacia fimbriata	25	13	10	17	14	ACT(d), Vic(s), SA
Acacia flexifolia	21	16	1	10	19	-
Acacia floribunda[6]	29	19	10	12	1	ACT(d), Vic, Tas, SA, WA
Acacia howittii[6]	48	30	14	17	76	ACT(d), Vic, SA?
Acacia iteaphylla[6]	16	10	3	6	2	NSW
Acacia leucoclada / parvipinnula	10/12	7/10	5/4	9/2	1	-
Acacia longifolia[6]	26	15	5	17	61	Vic, SA, WA
Acacia melanoxylon[6]	115	45	62	38	110	WA
Acacia rubida	23	15	5	14	40	-
Acacia sertiformis	1	1	1	1	6	-
Acacia stricta	25	15	0	8	69	-
Acacia terminalis[6]	46	19	13	18	1	ACT(d)
Acacia uncinata	29	13	6	12	1	-
Acacia venulosa	12	8	3	8	16	-
Acacia verniciflua	16	11	4	11	8	-
Acacia viscidula[6]	26	17	13	10	133	-

1 . From the Living Collection Database http://www.anbg.gov.au/cgi-bin/stock.

2. A single planting may be one or more plants; the number of individuals planted in each planting event is not retained in the database.
3. A "current" planting means one or more of the plants is still alive.
4. Number of different parent plants used in planting events (a rough measure of the number of genotypes planted). It does not take account of whether multiple plantings for each species were from germinated seed or from cuttings; the former would have greater genetic variability than the latter.
5. From the Australian Plant Census http://www.anbg.gov.au/chah/apc/.
6. Species on the ANBG weed list (Anon 2007).

Table 10. Frequency of *Acacia* plantings in ANBG.

Number of plantings	Species	
	Number	%
1-10	383	72.4
11-20	82	15.5
21-30	39	7.4
31-40	12	2.3
41-50	7	1.3
51-60	3	0.6
91-100	2	0.4
111-120	1	0.2
Total	**529**	**100**

4.2.3 Proximity. The proximity of natural areas in the Gardens to beds with cultivated species appears relevant to whether a species will naturalise, with planted species close to natural areas probably having more opportunity to naturalise and become invasive in them. For the abundant native species sourced solely from the Gardens, this can be demonstrated by comparing those sections of the Gardens with the highest number of woody weed plants removed, with sections where the species were known to have been planted. The comparisons (Table 11) show the following.

- *Acacia stricta*, *A. viscidula* and *Kunzea flavescens* were abundant in two relatively natural sections where they had been planted (sections 164 and 168). Approximately 140-145 adventive *Kunzea flavescens* plants had originated from just 10 mature, cultivated plants and spread into adjacent areas; because of the species' apparently strongly invasive nature, ANBG staff decided to de-accession and remove these original plants as well as the naturalised ones.
- *Acacia extensa*, *A. howittii*, *A. longifolia*, and *A. stricta* were abundant in section 89 which is adjacent to Section 77 that contained plantings of each species.
- *Acacia howittii*, *A. stricta*, *A. viscidula* and *Grevillea* aff. *rosmarinifolia* were all abundant in the Northern Annex adjacent to cultivated sections 164 and 184 where each species had been planted.
- *Pittosporum undulatum* was most abundant in sections near the rainforest gully where many plantings had also been recorded.

Proximity to plantings is not always a good indicator of the likelihood of a species becoming naturalised or invasive, as two of the abundant species that had naturalised had not been planted in adjacent sections (Table 11).

- *Billardiera heterophylla* was abundant in sections near the rainforest, but no plantings have been recorded there; the nearest sections (96 and 111) to the weeding area were 100-200 m from the densest infestations of this species.
- *Dodonaea triangularis* was present in a localised area in the upper part of Section 188 near the ANBG boundary fence and in the adjacent Northern Annex; the closest planting was in section 88, some 230-250 m away.

Table 11. Distribution of abundant weedy species and nearest ANBG plantings.

Species	Sections where largest number of plants were removed	Adjacent or nearby sections where plantings have been recorded[1]
Acacia extensa	89	77
Acacia howittii	188, N Annex	77, 165, 184
Acacia longifolia	89, 93, N Annex	77
Acacia melanoxylon	186	46, 64, 104, 140
Acacia stricta	89, 164, 184, N Annex	77, 164, 184
Acacia viscidula	164, 184, N Annex	164, 184
Billardiera heterophylla	89, 93, 185, 186, 187, 188, S Annex	96, 111
Dodonaea triangularis	188 & adjacent N Annex	88
Grevillea aff. rosmarinifolia	N Annex	184
Kunzea flavescens	89, 164, 166	73, 98, 164, 184
Pittosporum undulatum	185, 186, 187, 188	62, 64, 104, 140, 218, 219

1. From the Living Collection database http://www.anbg.gov.au/cgi-bin/stock.

4.3 Inherent attributes

The opportunity for seeds of cultivated plants to disperse into natural areas of the Gardens is affected by the level of seed production (how many seeds each plant produces), how long the cultivated plants remain alive, and how seeds are dispersed. Other factors pertinent to species becoming naturalised and possibly invasive include plant growth rates, age to first flowering, and seed longevity (Mulvaney 1991).

4.3.1 Seed output. Some of the abundant weedy species, such as *Acacia baileyana*, *A. decurrens*, *A. melanoxylon* and *Billardiera heterophylla* and probably *Kunzea flavescens* can produce a large number of seeds each year[8]. The three acacias and the *Kunzea* are also relatively long-lived trees, so all would have a high opportunity to become naturalised and locally invasive. Gallagher et al. (2011) reported that *Acacia* species growing outside Australia were more likely to become invasive if they were trees or tall shrubs, while Gibson et al. (2011) found that in overseas countries invasive *Acacia* species reached reproductive maturity earlier than non-invasive species. Many of the native species removed during the weeding program are cultivated shrubs that are probably shorter-lived and thus may have less opportunity to naturalise and then become invasive, especially if their seed output is low. A rough indication of the survival rates of species planted out in the Gardens can be gained from the Living Collection database. For example, of the 529 *Acacia* species with plantings recorded in the Gardens (Section 4.2.2), 145 species (27%) are no longer represented by living plants[9]. Low persistence time could reduce the ability of species to become weedy.

4.3.2 Seed dispersal. Naturalised, invasive woody weed species frequently have bird-dispersed succulent fruit, or seeds dispersed by wind or ants (Berry & Mulvaney 1995). Of the 26-30 exotic species removed during the weeding program (Appendix 2) 18 have bird-dispersed succulent fruit. At least two have seeds that are wind-dispersed and one has ant-dispersed seed.

All the native woody weed species removed as part of the weeding program appear to reproduce by seed, but few data are available on the dispersal mechanisms. Reported and other probable mechanisms are shown in Appendix 1, but no conclusions can be drawn because of the high number of guesses!

[8] RW Purdie, personal observations.
[9] Based on stocktake records.

Of the 13 abundant native species (tables 6 and 8, and Appendix 1), birds and ants are known to disperse the seeds of *Acacia baileyana* and *A. decurrens* and probably also *A. melanoxylon* and *A. howittii*. The semi-succulent fruit of *Billardiera heterophylla* and sticky seeds of *Pittosporum undulatum* are also bird-dispersed. The seeds of the other abundant *Acacia* species and of *Grevillea* aff. *rosmarinifolia* are probably dispersed by ants, while those of *Kunzea flavescens* are most likely wind-dispersed. Species with bird-dispersed seed are probably spread further than those with ant-dispersed seed; the wide distribution of weedy *Billardiera heterophylla* plants compared with the restricted distribution of cultivated plants in the Gardens is an example. However, the distribution of *Acacia stricta*, *A. viscidula* and *Grevillea* aff. *rosmarinifolia* in the Northern Annex suggests that over time, ants can distribute seeds 10-15 m or more away from original plantings.

4.4 Environmental suitability

Species are more likely to naturalise in areas with similar environmental conditions to their natural habitat or if they occur naturally over a wide range of climate, soil and vegetation types (Mulvaney 1991; Gallagher et al. 2011; Hui et al. 2011). The natural distribution of the native species removed during the weeding program is presented in Appendix 1. The data show:

- Of the 43 native weeds able to be identified to species level, 36 each occurs naturally in one or more states, including New South Wales, and all except *Acacia baileyana* have a natural widespread distribution in the latter. Three species are native just to south-west Western Australia, two are native just to south-east Queensland, and one is native just to each of Victoria and South Australia.
- Of the 13 abundant species, nine each occurs naturally in one or more states, including New South Wales, two are native just to Western Australia and one is native just to each of Queensland and Victoria.
- Of the 26 acacias identified to species level, 23 each occurs naturally in one or more states, including New South Wales, and one species is native just to each of Victoria, South Australia and Western Australia.

4.5 Conclusions

The low number of plants removed for the majority of native weed species derived solely from plantings within the Gardens suggests that currently these species pose no significant invasive risk. While almost 40 *Acacia* species have become naturalised in the upper bushland sections of the Gardens and parts of the adjacent annexes, they are a small proportion of all ANBG's cultivated *Acacia* species. Three quarters of the planted *Acacia* species also seem to have a low invasive potential in nearby bushland. If these findings are extrapolated to the rest of ANBG plantings, it would suggest that although almost 100 species in the Gardens (including acacias) have naturalised beyond the cultivated sections, the majority of planted woody species probably have a low naturalisation potential and thus currently do not pose a significant invasive risk. This appears consistent with an ACT-wide survey of environmental weed species that found native Australian species not indigenous to the ACT comprised "a relatively small proportion of the environmental weed flora" (Berry and Mulvaney 1995), although more naturalised native species might be expected in urban areas because of the proximity of bushland to public and private gardens.

Thirteen native species that have naturalised from ANBG plantings currently appear to be invasive in the Gardens, and if left unchecked, could further invade adjacent areas of Black Mountain Reserve. Eleven of these species are either known as invasive weeds in the ACT or considered to be potentially so, while two do not yet appear to have been recorded as being invasive elsewhere in Australia.

5. Management implications for the Gardens

Botanic gardens today are generally aware of the need to ensure they do not unintentionally become a source of invasive plant species. Usually they are aware of the risks involved in cultivating such species as part of their living collections, even when there may be good reasons for doing so (see for example Hulme (2011) and responses by Marris (2011) and Sharrock (2011)). Botanic gardens in Australia recently developed a Weed Risk Assessment Procedure, based largely on horticultural species introduced to Australia, to determine which species should be excluded from gardens' living collections because of their high risk of becoming environmental weeds (Virtue et al. 2008). The ANBG maintains a native species weed list (Anon 2007) first developed in 2000, and has a policy of removing naturalised plants from the Gardens where the Weed Risk Assessment Procedure shows species have a high weed potential (Croft 2006). The Gardens also maintains a list of real or potential native environmental weeds that are not to be sold from the premises (Winder 2004). ANBG staff have long recognised the possibility of planted species naturalising and invading Black Mountain Reserve. For example, in the early 1990s gardening staff removed naturalised Cootamundra Wattle on both sides of the ANBG western boundary fence as well as other naturalised *Acacia* species in upper parts of the Gardens[10].

The potential for ANBG to be a source of invasive woody weed species in the adjoining reserve can be minimised by continuing to actively manage both known invasive species and potentially invasive species within the Gardens. For the species identified in this report, especially *Acacia baileyana*, *A. decurrens*, *Billardiera heterophylla* and *Pittosporum undulatum*, management strategies could include one or more of the following:

- Remove all extant plantings and all self-sown plants of the invasive species from all cultivated beds, paying special attention to beds near natural areas of the Gardens.
- Retain extant plants in, and restrict new plantings of the invasive species to, those sections of the Gardens furthest from the Reserve.
- Continue to retain the natural sections of the Gardens adjoining the boundary fence as buffer areas where no further plantings will be made.
- Regularly check the buffer areas for invasive species and remove any plants found.
- Review the ANBG Plant Removal Policy (Croft 2006) and update it as necessary to reflect special needs arising from the Gardens' location adjoining the Reserve and current knowledge about the Reserve's conservation values.
- Amend the ANBG weed list (Anon 2007) and the Winder (2004) list of native environmental weed species not to be sold from the Gardens to reflect the findings in this report.

Weeding programs in the buffer and nearby natural sections of the Gardens should also target, for removal, any other native species found to have become naturalised: although not currently invasive, some species could be 'sleeper weeds' that may become so (Groves 1999). The comment by Reid and Murphy (2008) that a single *Acacia* plant "may be surrounded by enough soil-stored seed to constitute a major weed invasion when germination conditions occur … [and enable] a potential weed to progress from an apparently benign state to an environmentally harmful one in a very short time span" is highly relevant to the Gardens.

It will be particularly important to check all the areas covered in the FoBM weeding program on an annual basis for at least the next 2-3 years, as many of the species removed are likely to have an abundant soil seed store there. Checks at around five year intervals as part of an ongoing program will also be necessary to remove any native and exotic species re-introduced into the areas, as well as plants that have germinated from long-lived seeds in the soil. The Friends of Black Mountain and

[10] D. Mallinson, ANBG, pers. comm. June 2014

the Friends of the Australian National Botanic Gardens could continue to be actively involved in such programs.

The findings in this report suggest that the Weed Risk Assessment Procedure tool will not always identify high risk weed taxa. However potential weediness of species included in Gardens plantings should continue to be assessed, especially for known local weedy genera such as *Acacia* and *Grevillea*. Strategies to help minimise the chance of more native species naturalising in the Gardens and possibly becoming invasive could include one or more of the following.

- Remove all remaining cultivated plants from the buffer sections of the Gardens unless the species are not represented elsewhere in the ANBG Living Collection. This is particularly important for Section 188 where planted eucalypts appear to have started naturalising.
- Recognise that species with naturally widespread distributions in New South Wales have a relatively high probability of naturalising.
- Continue to use knowledge of species' naturalisation and invasiveness elsewhere in Australia, and knowledge of seed and fruit dispersal, to predict which species might become invasive in Canberra.
- Ensure that fewer than ten plantings are made in the Gardens of any species considered likely to be invasive.

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Appendix 1. Native woody weed species not indigenous to Black Mountain removed during the weeding program.

Species	Type[1]	Number of plants removed				Species' Origin[2]	Recorded as Naturalised[2,3]	Weed Pot'l[4]	Dis-persal[5]
		S-Annex	ANBG	N-Annex	Whole Area				
Acacia baileyana[6,7]	W	85	560	75	720	N	Q, N, A, V, S, W	HWP	A,B
Acacia binervata[6,7]	E	2	2		4	Q, N	-		A?
Acacia boormanii[7]	E		3		3	N, V	A		A?
Acacia cardiophylla[6]	E		5		5	N	A(d)		A?
Acacia covenyi	E		1		1	N	-		A?
Acacia cultriformis[6,7]	E		15	1	16	Q, N	A(d)	LWP	A
Acacia decurrens[7]	W		93		93	N	Q, A, V, T, S, W	HWP	A,B
Acacia elata[6,7]	E		2		2	N	A(d), V, W (s)	HWP	A,B
Acacia extensa[7]	E		75		75	W	V		A?
Acacia falcata	E		2	7	9	Q, N	-		A?
Acacia fimbriata	E		14		14	Q, N	A(d), V(s), S		A?
Acacia flexifolia	E		12	7	19	Q, N, V	-		A?
Acacia floribunda[6,7]	E		1		1	Q, N, V	A(d), V, T, S, W		A?
Acacia howittii[6,7]	E		61	15	76	V	A(d), V, S?		A,B?
Acacia iteaphylla[7]	E		2		2	S	N, V, S, W	HWP	A?
Acacia leucoclada / parvipinnula	E			1	1	Q, N / N	-		A?
Acacia longifolia[6,7]	E		59	2	61	Q, N, V, T, S	A (f), V, S, W		A?
Acacia melanoxylon[6,7]	E	41	68	1	110	Q, N, A, V, T, S	W		A,B?
Acacia rubida	W	6	34		40	Q, N, A, V	-		A?
Acacia sertiformis	E		5	1	6	Q, N	-		A?
Acacia stricta	E		49	20	69	Q, N, V, T, S	-		A?
Acacia terminalis[7]	E		1		1	N, V, T	A (d)		A?
Acacia uncinata	E		1		1	N	-		A?
Acacia unknown (9-13 spp)	E		130		130		-		
Acacia venulosa	E		15	1	16	Q,N	-		A?
Acacia verniciflua	E		8		8	Q, N, A, V	-		A?
Acacia viscidula[7]	E		102	31	133	Q, N	-		A?

Species	Type[1]	Number of plants removed				Species' Origin[2]	Recorded as Naturalised[2,3]	Weed Pot'l[4]	Dis-persal[5]
		S-Annex	ANBG	N-Annex	Whole Area				
Babbingtonia sp.	E		4		4		-		W??
Billardiera heterophylla[6,7]	E	180	697		877	W	N, A, T, S	HWP	B
Callistemon sp.	E		10		10		-		W??
Callitris sp.	E		39		39		-		W??
Cassinia sp.	E		3		3		-		W??
Chenopodium sp.	?	1			1		-		
Correa reflexa	E		3		3	Q, N, A, V, T, S	-		
Crowea sp.	E		3		3		-		
Darwinia citriodora	E, LS		1	15	16	W	S		
Dodonaea sp. (pinnate lf)	E		1		1		-		
Dodonaea triangularis[6]	E		50	105	155	Q, N	-		
Eucalyptus globulus[7]	?	1			1	N, V, T, S	A, W	LWP	W
Grevillea aff. *rosmarinifolia*[6,7]	E			140	140	N, V	-		A?
Grevillea arenaria[7]	LS			35	35	N	-		A?
Grevillea juniperina[6,7]	E	1			1	Q, N, A	-		A?
Grevillea juniperina CV1[7]	LS			15	15		-		A?
Grevillea juniperina CV2[7]	LS			20	20		-		A?
Grevillea patulifolia	E	4			4	N, A, V	-		A?
Grevillea robusta	E		2		2	Q, N	N		A?
Grevillea rosmarinifolia[6,7]	E		1		1		Q, A, S	M-HWP	A
Grevillea unknown (9-12 spp)	E		45	6	51		-		
Hakea sp.	E		1	3	4		-		W??
Hibbertia scandens[7]	E		1		1	Q, N	-		
Kennedia rubicunda[7]	E		1		1	Q, N, V	V, T		A??
Kunzea flavescens[7]	E		165	1	166	Q	-		W??
Lasiopetalum sp.	E		6		6		-		
Leptospermum sp.	E		10		10		-		W??
Melaleuca sp. 1	E		5		5		-		W??
Melaleuca sp. 2	E		22	2	24		-		W??

Species	Type[1]	Number of plants removed				Species' Origin[2]	Recorded as Naturalised[2,3]	Weed Pot'l[4]	Dis-persal[5]
		S-Annex	ANBG	N-Annex	Whole Area				
Melicytus dentatus[7]	E	1	1	3	5	Q, N, A, V, T, S	-		B??
Notelaea sp.	E		26		26		-		B??
Passiflora sp.[6]	E		1		1		-		B??
Persoonia linearis	E	1			1	Q	-		B??
Persoonia unknown (4 spp)	E		10		10		-		
Pittosporum angustifolium	E		3	10	13	Q, N, V, S, NT, W	-		B??
Pittosporum undulatum[7]	E		305	1	306	N, V	N, V, T, S, W	HWP	B
Platysace sp.	E		1		1		-		
Prostanthera sp.	E		1		1		-		
Pultenaea sp.	E		3		3		-		
Solanum sp. 1	E		17		17		-		
Solanum sp. 2	E	45			45		-		
Tasmannia sp.	E		2		2		-		
Zieria sp.	E		8		8		-		

1. Type:
   E = Escapee (species that has naturalised from cultivated plants in ANBG)
   LS = Species used for landscaping along Frith Road extension (towards ANU quarry/mine)
   W = Widespread species considered a weed on Black Mountain by Gray & McKee (1969)
2. State of origin and state where naturalised: data derived from the Australian Plant Census (http://www.anbg.gov.au/cgi-bin/apclist).
   Q = Queensland, A = Australian Capital Territory, N = New South Wales, NT = Northern Territory, S = South Australia, T = Tasmania, V = Victoria, W = Western Australia
3. Naturalised status: d = doubtfully; f = formerly; s = sparingly
4. Weed Potential in the ACT (after Berry & Mulvaney 1996): HWP = High Weed Potential; M-HWP = Medium to High Weed Potential; LWP = Low Weed Potential.
5. Dispersal mechanism where known: A = Ants, B = Birds, W = Wind. For entries with a "?" the dispersal mechanism has been assumed from the fruit type and by comparison with known species in the same genera (based on Berry & Mulvaney 1996), with additional data for some species from the Weeds in Australia database, http://www.environment.gov.au/cgi-bin/biodiversity/invasive/weeds/weedspeciesindex.pl?id=701&startLetter=S&IndexBy=comname, accessed June 2014. Species with "??" are guesses based on RW Purdie's personal knowledge of taxa.
6. Species recorded as a weed in relatively undisturbed vegetation on Black Mountain outside ANBG (Purdie 2009).
7. Species on the ANBG weed List (Anon 2007).

Appendix 2. Non-native (exotic) woody weed species removed during the weeding program.

Species		Number of plants removed			
		S Annex	ANBG	N Annex	Whole area
Berberis aquifolium	Mahonia	5			5
Celtis australis	Lote Tree		1	3	4
Cortaderia sp.	Pampas Grass	3			3
Cotoneaster glaucophyllus	Large-leaved Cotoneaster	1			1
Cotoneaster rotundifolius	Cotoneaster	20			20
Cotoneaster sp.	Cotoneaster		27		27
Crataegus monogyna	Hawthorn	9			9
Crataegus sp.	Hawthorn		13	3	16
Fraxinus angustifolia	Ash Tree	230		13	243
Genista monspessulana	Montpellier Broom			13	13
Hedera helix	English Ivy	1	14		15
Hesperocyparis arizonica	Arizona Cypress			15	15
Ligustrum sinense	Chonese Privet		17	1	18
Lonicera japonica	Japanese Honeysuckle		5	45	50
Malus? sp.	Apple	1			1
Nandina sp.	Sacred Bamboo		2		2
Photinia serratifolia	Photinia		1	1	2
Prunus sp.	Plum or Peach	1			1
Pyracantha sp.	Firethorn	1	11	13	25
Quercus sp.	Oak	1			1
Rosa sp.	Briar	10			10
Rubus sp.	Blackberry		34	28	62
Sorbus domestica	Service Tree			1	1
Unknown deciduous spp			3		3
Unknown introduced spp			3		3
Vitis vinifera	Grapevine			1	1