Black Mountain Symposium 2018 Background Paper No. 5

Vascular plants of Black Mountain, 1969–2017

Rosemary W Purdie

Centre for Australian National Biodiversity Research and Australian National Herbarium, GPO Box 1700, Canberra ACT 2601

Abstract. A current list of fern, conifer and flowering plant species occurring on Black Mountain was compiled largely from specimens in the Australian National Herbarium. Species' records to the end of 1969, 1980, 2012 and April 2017 allowed cumulative species presence to be tracked and changes in distribution and abundance of some species assessed. The total number of species recorded in the study area increased from 508 at the end of 1969 to 728 by April 2017. Over that time, the proportion of species indigenous to the area dropped from 63% to 54%, while introduced native species rose from 1% to 12% of the flora. Around 107 species recorded by the end of 1979 have not been relocated since, the most recent record of some species 63–82 years ago. For these taxa, data are available only to confirm two native and two exotic species have become locally extinct; each had a very restricted distribution in the area. The current flora (species with a verifiable record on Black Mountain over the last decade) comprises 593 species—17 ferns, 4 conifers and 572 flowering plants—of which 56% are native, 43% introduced and 1% of uncertain origin. The introduced natives include 33 shrub species used for road landscaping, 58% of which have naturalised (some into the reserve). Control of the major exotic and introduced woody species will remain a future management priority. Compared with other locations containing similar vegetation, Black Mountain has a high total number of species recorded, but this appears to reflect high search effort rather than intrinsic high floristic richness. The number of its native species per hectare (including orchids) does not appear to be unusually high in the ACT context. The current comprehensive knowledge of Black Mountain's vascular species provides a benchmark for tracking changes in its floristic diversity over future decades.

1. Introduction

Black Mountain gained prominence botanically in the early 1900s because of Walter Burley Griffin's proposal to site a botanical reserve on its southern lower slopes, and later to include it in his 'coloured hills' concept for Canberra (Gray 1999). In 1916 he proposed to plant the area with white- and pink-flowered shrubs (mostly various species of *Prunus* such as Japanese Peaches, Plums, Cherries and Almonds), changing his mind in 1918 to use *Acacia* or *Pyracantha* plants, and a year later deciding instead to use exotic ground covers. However, there is no record of any plantings taking place (Gray 1999). Professional botanists had been studying plants on the mountain long before it was formally declared a reserve in 1970. Since the first herbarium specimen was collected there in October 1927, several thousand more have been lodged in the Australian National Herbarium in Canberra (Purdie 2018a, 2018b). These specimens provide an invaluable record of the area's plant diversity and how it has changed over the decades.

The first comprehensive list of plants in the Black Mountain area was published by Gray and McKee (1969), covering ferns, conifers and flowering plants. Each species listed was given a distribution and abundance rating and assigned a herbarium specimen voucher. The area covered by Gray and McKee (1969) (Fig. 1a) encompassed areas now called Black Mountain, Bruce Ridge, Aranda Bushland and part of the suburb of Aranda (Fig. 1b).

Preparation of an up-to-date list of plants occurring on just Black Mountain commenced in early 2013, following reactivation of the Friends of Black Mountain (Beveridge 2018). It built on the Gray and McKee list, focussing on Australian National Herbarium records of specimens collected from Black Mountain to the end of 2012, and was supplemented by published sources of information. An initial analysis of the draft list in late 2013 showed that around 470 species in the Gray and McKee list from 1969 (hereafter called the GMcK List) probably occurred on Black

Mountain. The tally recorded there had increased to over 600 species by the end of 2012. Surprisingly, around 57% of these had not been recorded on the mountain (through herbarium specimens or reliable observational records) for between 30 and 60 or more years. The 57% of 'missing' species included many that were widespread and abundant on Black Mountain, but the metric raised questions about the status of other taxa. Were any weedy species that had naturalised in the area no longer present, but more importantly, had any species occurring naturally there become locally extinct?

This paper describes the compilation of an up-to-date list of plants on Black Mountain, summarises the results of relocating the 'missing' species, and discusses current knowledge of the area's plant diversity, changes to it since 1969, and some implications for future management of the area.

2. Methods

2.1 Compiling a draft list of vascular plants on Black Mountain

2.1.1 Study area

For the purpose of this study, Black Mountain was defined as the area bounded by Barry Drive, Belconnen Way, Caswell Drive, Parkes Way, Frith Road (excluding the fenced-in parts of the ACTEW substation), and the southern and northern annexes of the Australian National Botanic Gardens (ANBG) (see Fig. 1b). It excluded car parks and associated landscaped areas within the loop created by Black Mountain Drive adjacent to Telstra Tower. The study area is approximately 500 ha in extent and encompasses, but is slightly larger than, Black Mountain Nature Reserve (429 ha) due to the inclusion of the two ANBG annexes (each contiguous with the reserve) and land between the reserve boundary fence and adjacent roads. The current study area differs from the 1969 GMcK List area (Fig. 1b) in several ways. It excludes Bruce Ridge, Aranda Bushland and adjacent suburbs, land now under Parkes Way, and bushland between Frith Road/Barry Drive and Dryandra Street. It includes two areas excluded by Gray and McKee (1969), viz. the south-west part of the reserve (formerly called Smith's Paddock) and bushland between the Botanic Gardens Track (fire trail) and the ANBG western boundary fence. The geology, soils and vegetation of the area are described in Finlayson (2018), Tongway (2018) and Doherty (2018a) respectively.

2.1.2 Data sources

Initially all the names of plants in the GMcK List were checked and updated as necessary to current nomenclature in the Australian Plant Census (Council of Heads of Australasian Herbaria 2017). Where taxa were under revision in 1969 (e.g. *Wahlenbergia*; *Poa caespitosa auct*.-group) or in need of it (e.g. *Vittadinia*) (Gray and McKee 1969), the names of species resulting from subsequent revisions and recorded from Black Mountain were used for the draft list.

Because the GMcK List covered a much greater area than that defined for this study (hereafter called the study area; Fig. 1b), an attempt was made to exclude Gray and McKee species that occurred outside the latter. All species in the GMcK List were assumed to have a high probability of occurring in the current study area if they had a distribution rating of widespread, sparse, restricted or rubbish dump area (see Table 3), and an abundance rating from common to not common (see Table 4). These species were retained in the draft Black Mountain list. Any species with a very restricted distribution rating and a rare or once collected abundance rating was omitted from the draft list if the information on the herbarium voucher specimen clearly showed it lay outside the current study area.[1] In practice, only a small number of species could be omitted in this way, as most of the herbarium specimens collected prior to 1969 had a general location of "Black Mountain" and no additional information to help pin-point their exact collection locality.

Once the 1969 list had been cleaned up, the Australian National Herbarium Specimen Information Register database (ANHSIR) was interrogated for all specimens with a "Black Mountain" collecting

[1] An example of this was *Helminthotheca echioides* represented by a single herbarium specimen from Black Mountain collected in 1962 from "Near farmhouse at junction of Weetangera Road and Dryandra Street", i.e. located north of the current junction of Kunzea Street with Dryandra Street on the slopes of Bruce Ridge.

Fig. 1. a) Top: map of "Black Mountain and environs" area from Gray and McKee (1969). b) Bottom: 1969 map area transposed into Google image (solid red line) compared with the current Black Mountain study area (dotted red line).

locality. Species with a herbarium specimen collected prior to 1970 but missing from the GMcK List were added to the draft Black Mountain list unless the specimen information clearly indicated it lay outside the current study area. These included riparian species present only along the Molonglo River or recorded on Black Mountain Peninsula. Post-1969 specimens with well described locations that clearly lay outside the current study area were also excluded. Species represented by all other specimens were retained for the draft list even if their described location might be outside the study area. This mostly applied to specimens with a "west side of Black Mountain" location.

Where necessary, herbarium specimens were re-examined to check the plant's identification according to current knowledge, and the names corrected if the original identification was found to be incorrect[2]. Other data sources used to compile the draft list were those with reliable plant identifications for Black Mountain Nature Reserve and the ANBG northern and southern annexes, viz:

- orchid species listed in Jones et al. (2008);
- records of the Friends of the Aranda Bushland (2007, 2010);
- records in the Wednesday Walks plant lists of the Australian Native Plant Society (2008–2017);
- records from the ACT vegetation database managed by the ACT Government;
- species listed in Mulvaney (2014);
- field records of Ward (unpublished), Doherty (unpublished) and Purdie (unpublished); and
- verifiable photo records in Canberra Nature Map (http://canberra.naturemapr.org).

Other publications with information on Black Mountain's vegetation and plants were checked and species added to the draft list if not already included (e.g. some species from Adams (2010) and Department of Capital Territory (1980)). For each species, the year of last collection/observation was recorded in the periods to the end of 1980 and 2012 to provide a broad measure of cumulative species' presence over time.

2.2 Relocating the 'missing' species on Black Mountain

Active searching for the 'missing' species was carried out from December 2013 to April 2017, with maximum effort during the main flowering periods in spring and early summer. The study area was visited 3–4 times a week for 2–3 hours a time from January to April/May each year and then from August to December, the amount of time spent searching each month tailored to the local conditions. Outside the peak flowering periods, the area was visited approximately once a week.

The paucity of detailed location and habitat data on the herbarium specimens of most of the 'missing' species and lack of familiarity with many of the taxa (especially herbs, grasses and grass-like plants) precluded site- and species-specific searches. A search pattern similar to the random meander technique (McCaffrey et al. 2014) was therefore adopted. It allowed the whole study area to be covered but involved a different (random) route for each search period. The different distinct habitat types present in the area (based on slope, aspect and vegetation) were traversed regularly, and specific habitats described on herbarium specimens (such as "wet grassland", "small area of permanent seepage" or "Open weedy area towards summit on southern side of mountain") searched repeatedly.

Any species in the draft list for which there was no specimen in the Australian National Herbarium for 30 or more years was recollected and the specimen added to its collections. When the search for 'missing' species resulted in the location of a taxon not previously recorded for the study area, a voucher specimen was collected and lodged in the herbarium.

[2] For example, closer examination of a specimen collected in 1987 and originally called *Acacia pycnantha* (Golden Wattle) was found to be *Acacia penninervis* var. *penninervis* (Mountain Hickory).

2.3 Finalising the list of vascular plants on Black Mountain

2.3.1 Plant nomenclature

All species' family and scientific names were checked against the latest data in the Australian Plant Census (Council of Heads of Australasian Herbaria 2017). Any discrepancies in nomenclature were clarified with B Lepschi, Curator, Australian National Herbarium, except for orchid names that were clarified with M Clements, Australian National Herbarium.

The scientific and common names in the final list follow those in the ACT Plant Census Version 4.0 (Lepschi et al. 2017) except for one-off occurrence records (including some landscaping species) that it does not include. The latter follow Australian Plant Census scientific nomenclature, and common names from the New South Wales online flora (http://plantnet.rbgsyd.nsw.gov.au/floraonline.htm). Hybrid taxa were omitted from the final list; although some (e.g. *Acacia baileyana* × *A. decurrens*) are easy to identify, many are not, and hybrid taxa were poorly represented in herbarium collections.

2.3.2 Criteria for including or excluding species

All species in the draft list were re-assessed in mid-2017 for inclusion in the final list, using knowledge of the study area gained from the intensive searches for the 'missing' species. Specialist knowledge of other botanists (mostly in the Australian National Herbarium and in the ACT Government) relating to the nomenclature and/or distribution of species in the ACT and surrounding areas was also used, and some herbarium specimens rechecked.

All species in the draft list were retained in the final list unless they fell into one of the following categories.

- *Dubious determination or name change*. This included taxa whose name had been changed as a result of recent taxonomic revisions or after further examination of a herbarium specimen, or species that lacked any herbarium specimen for checking but that were believed to have been mis-identified based on knowledge of the species' habitats and wider distributions.
- *Clearly outside the study area*. This was based on the information on herbarium specimens coupled with on-ground knowledge of the species' habitats.

Species used for landscaping in the study area were retained in the final list, as were species for which the data were insufficient to determine with certainty whether they occurred within or only outside it. The latter were given the benefit of doubt and assumed to occur inside the area.

2.3.3 Species origin and habitat categories

Each species in the final list was assigned an origin category (Table 1). Habit categories (Table 2) were assigned to species on the basis of their mature growth form in the study area. In practice, these categories are not always clear-cut in the field.

2.3.4 Species distribution and abundance ratings

All species in the final list were assigned a distribution (Table 3) and abundance (Table 4) rating using the same notation as Gray and McKee (1969). As the latter provided no explanation of how they applied their distribution categories, the definitions shown in Table 3 were used for the final list. An additional rating was used for species that appear to be no longer present in the study area. It was assumed that Gray and McKee (1969) applied ratings based on their field knowledge of species and that of other CSIRO herbarium botanists who had been actively collecting in the study area during the 1960s (Purdie 2018a).

Current ratings in the final list were assigned to species from personal knowledge of the taxa gained during field work between December 2013 and April 2017, information associated with recent herbarium specimens (i.e. those collected over the last decade or so) and abundance records in Canberra Nature Map. Notes in Jones et al. (2008) and the field knowledge of local botanists were used to assign current distribution and abundance ratings to orchid species. The abundance of herbaceous species (forbs, grasses and graminoids) from 2013 to 2017 showed considerable

seasonal variation[3]. For these species, the highest abundance rating observed in the field or recorded elsewhere was used in the final list.

Table 1. Origin categories of species

Origin (Code)	Definition
Exotic (E)	Species introduced to Australia.
Native (N)	Species native to Australia and known or considered to be indigenous[4] to the study area.
Native Landscaping (NL; NL-NW)	Species native to Australia that have been used for landscaping along roads and/or car parks in the study area. Native landscaping species that have naturalised in the area are coded as NL-NW.
Native Weed (NW; NW-NL)	Species native to Australia but not occurring naturally in the study area (i.e. they have been introduced there). Native weed species that have also been used for landscaping are coded as NW-NL.
Uncertain (U)	Species native to Australia whose origin on Black Mountain is uncertain (i.e. it is unclear whether the species are indigenous to the area or have been introduced there).

Table 2. Growth form (habit) categories of species

Habit (Code)	Definition
Aquatic (A)	A perennial plant growing in permanent or semi-permanent water.
Climber (C)	A ground layer plant that climbs into other plants or twines its stems around those of other plants; the latter are also called twiners.
Fern (Fe)	An arborescent fern with a distinct trunk, or a herbaceous fern with rhizomes.
Forb (F)	A herbaceous plant (excluding grasses and graminoids) that lacks woody stems.
Graminoid (Gr)	A herbaceous plant with grass-like leaves.
Grass (G)	A plant in the family Poaceae.
Mistletoe (M)	A parasitic woody plant in the family Loranthaceae that grows on the branches of other woody species.
Shrub (S)	A woody plant usually less than 3 m tall with either a single woody main stem from which branches arise, or with several distinct woody stems arising close to ground level and branching higher up.
Subshrub (SS)	A small woody perennial usually less than 0.5 m tall, often with many soft-wooded slender stems arising from ground level.
Tree (T)	A woody plant usually with a single trunk and 3 m or more high.

[3] For example, the graminoid *Eleocharis atricha* (Tuber Spikerush) was the dominant ground cover in seepage areas in 2016 but absent from the same areas in the previous three years.
[4] Indigenous to an area means the species occurs there naturally, i.e. it has not been introduced by humans or because of human activities.

Table 3. Distribution ratings of species

Gray and McKee (1969)		Purdie (this study)		
Code	**Rating**	**Code**	**Rating**	**Definition**
w	widespread	w	widespread	Present throughout the study area for tree and shrub species, and in both dry sclerophyll forest and grassland for herbaceous species.
s	sparse	s	sparse	Widespread in the study area but with a patchy distribution (compared with "w"); present in several very different locations (e.g. S slopes, W slopes, N slopes etc.) and habitat types but not present everywhere.
r	restricted	r	restricted	Generally occurs in one specific habitat (e.g. creek lines; seepage areas; grassland), OR, it does not meet the sparse or widespread criteria as outlined above, and is known from >1 location.
vr	very restricted	vr	very restricted	Known to occur in only one location / small localised area.
R	Rubbish dump area	-	-	Refers to former dump to the NW of the CSIRO site. The code was not used in 2017, as the area had been rehabilitated.

Table 4. Abundance ratings of species

Gray and McKee (1969)		Purdie (this study)	
Code	**Rating**	**Code**	**Rating**
vc	very common	vc	very common
fc	fairly common	fc	fairly common
c	common	c	common
lc	locally common	lc	locally common
nc	not common	nc	not common; occasional
r	rare	r	rare
oc	once collected	oc	collected or recorded once
		le	presumed to be locally extinct, i.e. no longer present in the study area

3. Results

Overall, 773 vascular species with a location of “Black Mountain” on herbarium specimens have been recorded since October 1927. However, 30 of these (Appendix 1) were excluded from the final list, either because their name had been changed due to a taxonomic revision or because the species was, or was thought to have been, mis-identified. A further 15 species (Appendix 2) were omitted because there was sufficient evidence to conclude they occurred outside the study area. Species in the study area final list are shown in Appendix 3, which also indicates species that were recorded by the end of 1969, the year of species’ most recent record to the end of 1980 and to 2012, and species recorded between the start of 2007 and the end of April 2017 (the period defined in this study as representing the current flora).

3.1 All species recorded in the study area

After exclusion of the taxa as outlined above, a total of 728 species had been recorded in the almost 90 years to the end of April 2017 (see Table 5). They included 19 ferns, four conifers and 705 species of flowering plants (484 dicots, 221 monocots). Just over one third of all species were exotic, 54% were indigenous to the area, and 12% were Australian natives that had been introduced there (called native weeds in this study). The latter include 31 species used for landscaping, 17 of which had naturalised, and 53 species primarily introduced by non-human vectors or inadvertently (although two species had also been used for landscaping and naturalised).

The origin of eight species (1% of the total) is uncertain; they comprise two ferns (*Doodia australis*, *Cyathea australis*), five shrubs (*Olearia erubescens*, *Daviesia acicularis*, *Ozothamnus diosmifolius*, *Pomaderris angustifolia*, *P. discolor*) and one forb (*Viola caleyana*).

The distribution of growth forms among the plant groups is shown in Table 6. Thirty per cent of all species were woody, and included 144 shrub, 43 tree, 28 subshrub and three mistletoe species. The number of forbs (257 species) was slightly higher than the number of grasses and graminoids (102 and 118 species respectively). Ferns, climbers and aquatic species each comprised less than 3% of the total.

3.2 Cumulative plant diversity 1969–2017

On the basis of the available information, it was judged that 463 species in the GMcK List had a strong to reasonably strong probability that they were or could have been present in the study area (see section 2.1.2). Based on herbarium specimens alone, 508 species (i.e. 45 more than Gray and McKee reported) were judged to have been recorded in the study area between 1927 and the end of 1969. This latter figure was used to assess changes in the number of species recorded since 1969 (although the Gray and McKee figures are also shown in the following tables). Records for the post-1969 time intervals include herbarium or other specimens, reliable non-vouchered records and records in post-1969 publications.

3.2.1 Species by major group

The number of species in each plant group in the GMcK List and the cumulative numbers recorded for each group by the end of 1969, 1980, 2012 and April 2017 are shown in Table 7. The total number of plants recorded from the end of 1969 to the end of April 2017 increased by 43.4%, from 508 to 728 species. The number of dicot species increased by 50.8% over that time and the monocot species by 27.0%. The number of species newly recorded in the area increased by 6.3% over the 11-year period 1970–1980, by 17.6% over the 32-year period 1981–2012 and by 14.6% from the beginning of 2013 to the end of April 2017.

The 93 additional species recorded in 2013–2017 included five fern, three climber, 23 forb, 11 grass, five graminoid, one subshrub, 41 shrub and four tree species. Thirty-eight per cent of the species were exotic, 32% native weeds, and 11% native species used for landscaping. Only 15% of the species were considered indigenous to Black Mountain.

3.2.2 Species by origin

The cumulative number of indigenous species, introduced native species and exotic species recorded by the end of 1969, 1980, 2012 and April 2017 are shown in tables 8–10. The tables exclude the six species of uncertain origin (see section 3.1) and include comparable data for the GMcK List species recorded in the study area.

(a) Native species indigenous to the study area

The total number of indigenous species recorded from the end of 1969 to the end of April 2017 increased by 21.7%, from 322 to 392 species (Table 8). The number of indigenous dicot species increased by 16.6% over that time and monocot species by 26.8%. The number of native species recorded increased by 8.1% over the 11-year period 1970–1980, by 8.6% over the 32-year period 1981–2012, and by 3.7% from the beginning of 2013 to the end of April 2017.

Table 5. Number of species recorded, April 2017

Plant group	Origin	No. all records ≤2017	% of species in group	% of all species
Ferns	Native/indigenous	16	84.2	
	Native Weed	1	5.3	
	Uncertain	2	10.5	
	Total	**19**	**100**	**2.6**
Conifers	Native/indigenous	2	50	
	Exotic	2	50	
	Total	**4**	**100**	**0.6**
Dicotyledons	Native/indigenous	218	45.0	
	Native Weed	51	10.5	
	Native Landscaping	31	6.4	
	Exotic	178	36.8	
	Uncertain	6	1.2	
	Total	**484**	**100**	**66.5**
Monocotyledons	Native/indigenous	156	70.6	
	Native Weed	1	0.4	
	Exotic	64	29.0	
	Total	**221**	**100**	**30.4**
All species	**Total**	**728**		**100**

Table 6. Number of species recorded to April 2017 by growth form (habit)

	Number in plant group				Total	
Habit	**Fern**	**Conifer**	**Dicot.**	**Monocot.**	**Number**	**%**
Aquatic	-	-	1	2	3	0.4
Climber	-	-	11	-	11	1.5
Fern	19	-	-	-	19	2.6
Forb	-	-	257	-	257	35.3
Graminoid	-	-	1	117	118	16.2
Grass	-	-	-	102	102	14.0
Mistletoe	-	-	3	-	3	0.4
Shrub	-	-	144	-	144	19.8
Subshrub	-	-	28	-	28	3.9
Tree	-	4	39	-	43	5.9
Total	**19**	**4**	**484**	**221**	**728**	100

Table 7. Cumulative number of all species recorded and % change since the end of 1969

Broad Group	Gray and McKee (1969) list	Herbarium specimens ≤1969	All sources ≤1980	All sources ≤2012	All sources ≤April 2017	% increase ≤1969 to ≤April 2017
Ferns	8	11	14	14	19	72.7
Conifers	2	2	2	4	4	100.0
Dicots	297	321	337	412	484	50.8
Monocots	156	174	187	205	221	27.0
Total	**463**	**508**	**540**	**635**	**728**	**43.4**

Table 8. Cumulative number of indigenous species recorded and % change since the end of 1969

Broad Group	Gray and McKee (1969) list	Herbarium specimens ≤1969	All sources ≤1980	All sources ≤2012	All sources ≤April 2017	% increase ≤1969 to ≤April 2017
Ferns	8	11	14	14	16	45.4
Conifers	1	1	1	2	2	100.0
Dicots	171	187	198	211	218	16.6
Monocots	112	123	135	151	156	26.8
Total	**292**	**322**	**348**	**378**	**392**	**21.7**

(b) Native species introduced to the study area

The total number of introduced native species recorded from the end of 1969 to the end of April 2017 increased by 1267%, from 6 to 84 species, all except two of which were dicots (Table 9). The number of introduced native species recorded increased by 33% over the 11-year period 1970–1980, by 463% over the 32-year period 1981–2012, and by 87% from the beginning of 2013 to the end of April 2017. The 1981–2012 increase included 21 landscaping species and an additional 16 native weeds, while a further 10 landscaping species and 27 native weeds were recorded from 2013–April 2017.

Table 9. Cumulative number of introduced native species recorded and % change since the end of 1969

Broad Group	Gray and McKee (1969) list	Herbarium specimens ≤1969	All sources ≤1980	All sources ≤2012	All sources ≤April 2017	% increase ≤1969 to ≤April 2017
Ferns (weed)	-	-	-	-	1	
Dicots						
(weed)	(4)	(6)	(8)	(24)	(51)	
(landscaping)	-	-	-	(21)	(31)	
Total	4	6	8	45	82	1267
Monocots (weed)	-	-	-	-	1	
Total	**4**	**6**	**8**	**45**	**84**	**1300**

(c) Exotic species
The total number of exotic species recorded from the end of 1969 to the end of April 2017 increased by 37.1%, from 178 to 244 species (Table 10). The number of exotic species recorded increased by 1.7% over the 11-year period 1970–1980, by 15.5% over the 32-year period 1981–2012, and by 16.7% from the beginning of 2013 to the end of April 2017.

Table 10. Cumulative number of exotic species recorded and % change since the end of 1969

Broad Group	Gray and McKee (1969) list	Herbarium specimens ≤1969	All sources ≤1980	All sources ≤2012	All sources ≤April 2017	% increase ≤1969 to ≤April 2017
Conifers	1	1	1	2	2	100
Dicots	121	126	128	153	178	41.3
Monocots	44	51	52	54	64	25.5
Total	**166**	**178**	**181**	**209**	**244**	**37.1**

3.3 Species no longer present or not relocated in the study area, April 2017

3.3.1 Species no longer present
One native fern (*Blechnum cartilagineum*, Gristle Fern), three native dicots (*Bedfordia arborescens*, Tree Blanketleaf; *Eucalyptus rubida*, Candlebark; *Ozothamnus conditus*, Sprawling Everlastingbush) and three exotic dicots (*Cistus salviifolius*, Rock Rose; *Citrullus amarus*, Wild Melon; *Robinia pseudoacacia*, Black Locust) are considered to be no longer present in the study area. All appeared to have had a very restricted distribution, and sufficiently detailed location information was available to target searches for them, but none were relocated.

Gristle Fern and Black Locust were each recorded once from the north side of the study area in 1978 and 1980 (respectively), and Tree Blanketleaf once from the south-west creek area in 1995. All are assumed to have died out, probably because they were growing in an unfavourable habitat and/or failed to reproduce. Wild Melon, recorded in 1956 and 1962 and also assumed to have died out, appears to require regular, significant disturbance to persist (Lepschi 2018).

The indigenous Sprawling Everlastingbush was recorded in both 1961 and 1962 on the north-east side of Black Mountain and was probably destroyed when Barry Drive was constructed. The only tree of the indigenous Candlebark known from the area was destroyed by the widening of Caswell Drive as part of the Gungahlin Drive Extension works (Geue 2016). Works associated with the latter at Glenloch Interchange are also likely to have eliminated the Rock Rose population, recorded from the former Rani Road in 1999.

3.3.2 Species not relocated
By the end of the intensive search in the study area for taxa not recorded since 1980, 107 species (Appendix 4) had not been relocated by the end of April 2017. They included four believed no longer to be present there (*Blechnum cartilagineum*, *Ozothamnus conditus*, *Citrullus amarus* and *Robinia pseudoacacia*; see previous section). Each of the remaining 103 species still 'missing' was re-assessed in light of the knowledge of the study area gained from the 2013–2017 field work and from notes on the associated herbarium specimens. Species were then assigned to one of nine categories relating to the likelihood of the taxa still being present in the area or not (Table 11).

Categories 1–3 indicate species that probably are no longer present in the study area. Two exotic species (*Genista monspessulana*, Montpellier Broom; *Carpobrotus aequilaterus*, Chilean Pigface) were most likely destroyed by roadworks along Caswell Drive and Parkes Way respectively. The non-indigenous native *Goodenia ovata* and exotic *Lactuca saligna* (Wild Lettuce) appear to have been one-off adventive records on Black Mountain. Twelve exotic species reported by Gray and McKee (1969) only for the former rubbish dump area behind CSIRO are assumed to have been

destroyed when the dump was rehabilitated; most of the area is now part of the ANBG's landscape material storage facility.

Categories 4–6 indicate 10 species that, in hindsight, were probably collected from outside the study area. They include eight exotic species, six of which were probably associated with an area north of the current CSIRO grounds that was excluded from the current study area. Most of the six were taxa cultivated within nearby CSIRO experimental plots or glasshouses in the 1960s. Two native forbs, *Lotus australis* (Australian Trefoil) and *Swainsona monticola* (Notched Swainson-pea), both typically associated with grassland or grassy woodland vegetation (Eddy et al. 2011; Sharp et al. 2015), were most probably located on those parts of Black Mountain now on the west side of Caswell Drive.

Category 7 refers to species described on herbarium specimens as occurring in highly disturbed areas, and includes the indigenous forbs *Stuartina hamata* (Hooked Cudweed) and *Wahlenbergia gracilenta* (Annual Bluebell). These species may no longer be present in the study area if their original habitat was either along roadsides that have since been widened, or if located in what is now part of the nature reserve and subject to lower levels of disturbance since 1970.

The only species in Category 8, the indigenous herb *Wahlenbergia littoricola* subsp. *littoricola*, has previously been identified as *W. graniticola* and *W. communis*, both of which have been recorded on Black Mountain since 1980. Accurate identification relies on mature flowers, but none is present on the herbarium specimen, so it may represent a mis-identification.

Category 9 represents the balance of species (64 taxa) in the 'missing' list, all of which potentially could still occur in the study area, and includes 62% of all species not recorded there for 30 or more years. It contains all 39 of the missing indigenous species, comprising four shrub, one subshrub, eight graminoid, six grass, 18 forb, one aquatic and one fern species.

3.4 Current plant diversity of Black Mountain

3.4.1 Number of species

A total of 593 species has been recorded from the study area from 2007 to April 2017 (see column 12 of Appendix 3). They comprise 17 ferns, 4 conifers, 400 dicots and 172 monocots (Table 12), of which 56% are native, 43% introduced and 1% of uncertain origin.

The distribution of species' growth forms is summarised in Table 13. Just over one third of species are woody, comprising 130 shrub, 42 tree, 26 subshrub and three mistletoe species. The number of forbs (191 species) slightly exceeds that of grasses and graminoids (68 and 103 species respectively). Ferns, climbers and aquatic species together comprise only 5% of species.

Only 47 species (8% of the total) have a widespread distribution across the area (see column 11 of Appendix 3). The majority have a restricted or very restricted distribution (225 species (38%) and 116 species (20%) respectively). The remaining 205 species (35%) have a sparse distribution.

3.4.2 Changes in distribution and abundance since 1969

Distribution and abundance ratings for 1969 (column 7 of Appendix 3) and 2017 (column 11 in Appendix 3) were available for 363 taxa and are summarised in Table 14.

In both 1969 and 2017 the distribution of the majority of species was sparse (46% and 48% of species respectively) or restricted (26% and 34% respectively). Widespread species comprised 23% and 12% of the total in 1969 and 2017 (respectively) and species with a very restricted distribution 5% and 6% (respectively). Very few species had a very common abundance or were rare or once collected in 1969 and 2017. Overall, the proportion of species with an abundance rating from locally common to very common was higher than the proportion from once collected to not common (76% and 24% respectively in 1969; 52% and 48% respectively in 2017).

For a variety of reasons (discussed in section 4.1), the differences in distribution and abundance ratings for most individual species in 1969 compared with 2017 are unlikely to represent actual on-ground changes. The exceptions are species with a distribution rating of restricted or very restricted

in the GMcK List area, as these ratings would have been similarly applicable to the smaller current study area. For these species, change towards a more extensive distribution in 2017 may reflect on-ground change. All such species were thus examined to identify those for which the 2017 distribution was greater than that recorded in 1969.

Table 11. Number of 'missing' species by likely status on Black Mountain, April 2017

Categories, status code and status description			Origin of species				
			Indig-enous	**Native Weed**	**Exotic**	**Un-known**	**Total**
	Species probably no longer present						
1	DRW	Probably destroyed by roadworks	-	-	2	-	2
2	OOV	One-off record as a probable vagrant	-	1	1	-	2
3	RD	Associated only with rubbish dump in 1969 list	-	-	12	-	12
	Species probably outside the study area						
4	CSIRO	Species on E side of Black Mtn, often cultivated in CSIRO, and probable escapees into area N of CSIRO (excluded from 2017 area)	-	-	6	-	6
5	DHN	Conclusion based on 1969 distribution and herbarium specimen notes	-	-	2	-	2
6	GS	Probably a grassland species W or SW of 2017 area	2	-	-	-	2
	Other						
7	DS	Species associated with highly disturbed areas in 1969 and possibly no longer present due to decreased disturbance within the reserve or increased maintenance along roadsides	2	-	10	-	12
8	PMD	Possible mis-identification	1	-	-	-	1
9	**Species possibly still present**		34		29	1	64
		Total number of species	**39**	**1**	**62**	**1**	**103**

Table 12. Species recorded from 2007 to April 2017

Plant group	Origin	Number of species	% of species in group	% of all species
Ferns	Native/indigenous	14	82.4	
	Native Weed	1	5.9	
	Uncertain	2	11.8	
	Total	17	100	2.9
Conifers	Native/indigenous	2	50	
	Exotic	2	50	
	Total	4	100	0.7
Dicotyledons	Native/indigenous	186	46.5	
	Native Weed	50[a]	12.5	
	Native Landscaping	31	7.8	
	Exotic	128	32.0	
	Uncertain	5	1.3	
	Total	400	100	67.5
Monocotyledons	Native/indigenous	132	76.7	
	Native Weed	1	0.6	
	Exotic	39	22.7	
	Total	172	100	29.0
All species	**Total**	**593**		**100**

[a] Includes two species also used for landscaping.

Table 13. Growth form (habit) of species recorded from 2007 to April 2017

	Number in plant group				Total	
Habit	**Fern**	**Conifer**	**Dicot.**	**Monocot.**	**Number**	**%**
Aquatic	-	-	-	2	2	0.3
Climber	-	-	11	-	11	1.9
Fern	17	-	-	-	17	2.9
Forb	-	-	191	-	191	32.3
Graminoid	-	-	1	102	103	17.4
Grass	-	-	-	68	68	11.5
Mistletoe	-	-	3	-	3	0.5
Shrub	-	-	130	-	130	21.9
Subshrub	-	-	26	-	26	4.4
Tree	-	4	38	-	42	7.1
Total	**17**	**4**	**400**	**172**	**593**	

A comparison of the 1969 and 2017 distribution ratings of the 354 species for which data were available indicated that nine species with a very restricted rating in 1969 had a restricted rating in 2017 (Table 15). They included one tree, two shrub species, one grass and five forbs. Of the latter, *Galium aparine* (Cleavers), *Silene gallica* (French Catchfly) and *Veronica persica* (Creeping Speedwell) had only been associated with the rubbish dump in 1969 (R distribution rating) but were present in other parts of the study area in 2017. Five species with a very restricted distribution rating in 1969 had a sparse rating in 2017 (Table 15), suggesting they may have become more widespread over the intervening period. Four were trees or shrubs and one a climber. Three species (*Acacia penninervis*, Mountain Hickory; *A. rubida*, Red-leaved Wattle; and *Callitris endlicheri*, Black

Cypress Pine) had also increased in abundance over that time (from not common or rare, to locally common).

Table 14. Distribution and abundance ratings in 1969 and 2017

Abundance[a]	Distribution									
	Number of species in 1969					Number of species in 2017				
	widespread	**sparse**	**restricted**	**very restricted[b]**	**Total**	**widespread**	**sparse**	**restricted**	**very restricted**	**Total**
vc	6	-	-	-	**6**	4	-	1	-	**5**
fc	34	20	-	-	**54**	5	8	-	-	**13**
c	32	3	-	-	**35**	18	5	-	-	**23**
lc	10	118	51	3	**182**	11	85	47	3	**146**
nc	-	26	37	3	**66**	5	70	54	-	**129**
r	-	1	7	10	**18**	-	5	23	11	**39**
oc	-	-	-	2	**2**	-	-	-	8	**8**
Total	**82**	**168**	**95**	**18**	**363**	**43**	**173**	**125**	**22**	**363**
(%)	(23%)	(46%)	(26%)	(5%)		(12%)	(48%)	(34%)	(6%)	

[a] Abundance ratings: vc = very common; fc = fairly common; c = common; lc = locally common; nc = not common; r = rare; oc = once collected

[b] Includes R ratings, i.e. species only known from the rubbish dump in 1969.

Table 15. Species whose distribution rating changed from very restricted in 1969 to restricted or sparse in 2017

2017	1969 Distribution[a]/Abundance[b] (D/A) rating		
D/A rating	**vr/lc, R/lc**	**vr/nc, R/nc**	**vr/r, vr/oc**
r/lc	**Silene gallica* var. *gallica* **Vicia hirsuta*	**Galium aparine*	
r/nc	*Amphibromus nervosus* **Vicia sativa* subsp. *nigra*	*Kunzea parvifolia*	
r/r		**Veronica persica*	*Allocasuarina verticillata* **Ligustrum sinense*
s/lc	**Lonicera japonica*	*Acacia penninervis* var. *penninervis*	[#]*Acacia rubida* *Callitris endlicheri*
s/r			**Celtis australis*

[a] Distribution ratings: s = sparse, r = restricted, vr = very restricted (including R = rubbish dump).

[b] Abundance ratings: lc = locally common, nc = not common, r = rare, oc = once collected.

* Exotic species.

[#] Native species not indigenous to Black Mountain.

Of the 354 species for which 1969 and 2017 distribution ratings were available, 26 had a restricted rating in 1969 and a sparse rating in 2017 (Table 16). They included nine shrub species, one subshrub and ten herbaceous species comprised of three forbs, four graminoids and three grasses. Three orchids and one forb species had changed from a restricted distribution rating in 1969 to a widespread rating in 2017 (Table 16).

Table 16. Species whose distribution rating changed from restricted in 1969 to sparse or widespread in 2017

2017 D/A rating	1969 Distribution[a]/Abundance[b] (D/A) rating		
	r/lc	**r/nc**	**r/r**
s/c		**Tolpis barbata*	
s/fc	*Coronidium oxylepis* subsp. *lanatum* *Lepidosperma gunnii*		
s/lc	*Acianthus exsertus* *Diplodium revolutum* *Hakea decurrens* subsp. *decurrens* **Isolepis levynsiana* **Rubus anglocandicans* **Vulpia myuros* f. *megalura*	**Crepis capillaris* *Senecio bathurstianus*	*Veronica perfoliata*
s/nc	**Avena barbata* *Daucus glochidiatus* *Leucopogon fletcheri* subsp. *brevisepalus* *Omphacomeria acerba*	*Astrotricha ledifolia* *[#]Cassinia sifton* *Choretrum pauciflorum* **Crataegus monogyna* *Echinopogon ovatus* *Olearia microphylla* **Sisyrinchium rosulatum* *Thysanotus patersonii*	
s/r		*Echinopogon cheelii* *Veronica calycina*	
w/c	*Caladenia caerulea* *Pterostylis nutans*		
w/lc	*Gonocarpus tetragynus*		
w/nc		*Corunastylis clivicola*	

[a] Distribution ratings: r = restricted, , s = sparse, w = widespread
[b] Abundance ratings: c = common, fc = fairly common, lc = locally common, nc = not common, r = rare
* Exotic species
[#] Native species not indigenous to Black Mountain

4. Discussion

4.1 Methodological issues

Attempting to track changes in plant diversity from a 49-year-old publication (Gray and McKee 1969) relating to a larger area and from herbarium specimens collected over nine decades has inherent problems.

Changes in plant nomenclature and changing concepts of species could be addressed with a high level of confidence because of the voucher specimen cited for each species in the GMcK List, all herbarium specimens in the study area being available for comparison, and name changes for these specimens being recorded in ANHSIR. For taxa published as new species after 1969, including eight orchids described from 2006 to 2008 for which Black Mountain is the type locality (Purdie 2018c), it was possible to track their presence in the study area as the species were included in the

GMcK List but under earlier names[5].

The very general location data and little or no habitat information for many early herbarium specimens made it rarely possible to confidently exclude species from the study area. The lack of explanation about why Gray and McKee excluded 45 species with herbarium specimens from Black Mountain created more uncertainty, although logical reasons can be envisaged. For example, some of the 1969 herbarium specimens were probably collected after Gray and McKee (1969) was submitted for publication. Some species may have been located in parts of the current study area that were excluded from that of Gray and McKee (see Fig. 1b). Species represented by early herbarium collections (1927–1950s) may have been omitted if not recollected by the late 1960s.

Unless there was clear information to exclude a species from the study area, species based on herbarium collections were initially included in the draft list. This was largely on the assumption that much early collecting effort would have been focussed closer to ANBG, CSIRO and ANU, the home institutions of key botanists (Purdie 2018a), and access to the area from the 1960s would have been similar to today. Many of the roads on Black Mountain, including a sealed one to the summit, were constructed from 1952 to 1965 (Coyne 1969; Fraser 1981). While uncertainty remained about whether or not some collections were located in the study area, this did not affect the overall trends in species recorded there to 2017.

To assess changes in plant diversity over time, it was assumed that the GMcK List plus additional herbarium records provided a comprehensive 1969 benchmark, reflecting in part the large number of plants collected from Black Mountain in the 1960s (Purdie 2018a). The uneven rate of annual herbarium collections since then (Purdie 2018a) meant that only broad time intervals could be used to assess subsequent changes. The choice of 1980 to provide intervals of 1969–1980 and 1981–2012 was arbitrary, but influenced by the definition of naturalised status in version 3.0 of the ACT Plant Census: "Non-indigenous taxa previously recorded from the ACT, but for which no collections have been made within the past 30 years, are treated as Formerly Naturalised" (see Lepschi et al. 2017, which uses the same definition). The four time intervals used (to the end of 1969, 1980, 2012 and April 2017) were, however, sufficient to assess broad changes in cumulative species' presence in the study area.

Comparison of 1969 and 2017 distribution and abundance ratings for individual species was problematic. This was partly because the lack of definition of the terms in Gray and McKee (1969) made it difficult to know the degree of compatibility in applying the ratings in 2017, although their intuitive application based on field knowledge of the area was probably similar. Comparison of distribution ratings was further complicated by differences in the size of the 1969 and 2017 study areas and probable differences in search effort preceding these years. Abundance ratings in both years would have been affected by factors in the prior decade, such as environmental conditions (especially the amount of precipitation and its seasonality), presence and extent of the root-rot fungus *Phytophthora cinnamomi* (Pratt and Heather 1973; Taylor 1974) and fire history, including time since the last fire and its intensity (Murray and Lepschi 2004; Purdie 1977a, 1977b; Doherty 2018b). The frequency and nature of disturbances such as road works and grazing prior to 1969 and 2017 would also have influenced abundance ratings, especially for the south-east and south-west slopes of the study area (see Fig. 1a). The former had been cleared for grazing by the mid-1800s (Ryan 2011) and described in 1980 as covered in "almost complete Mediterranean weeds" (Department of the Capital Territory 1980). The south-west grassland area (Smith's Paddock) had long been grazed by sheep and cattle until the reserve was declared in 1970 (Fraser 1981). The nature, frequency and intensity of disturbances probably changed significantly once the area was managed for conservation. For all these reasons, differences between the 1969 and 2017 distribution and abundance ratings for individual species were considered unlikely to represent actual on-ground changes, except for species with a 1969 distribution rating of restricted or very restricted (see section 3.4.2).

[5] For example *Senecio phelleus*, described in 2004, was called *S. quadridentatus* in 1969 and included under that name in the GMcK List.

4.2 Changes in the number of species recorded between 1969 and 2017

While the number of species recorded on Black Mountain increased from 508 in 1969 to 728 by the end of April 2017 (Table 7), the proportion of ferns, conifers and flowering plants remained similar in 1969 (2.2%, 0.4% and 97.5% respectively) and 2017 (2.6%, 0.6% and 96.9% respectively). The proportion of dicots increased from 63.2% in 1969 to 66.5% in 2017, while the monocots decreased from 34.3% to 30.4% of the total over that time. The biggest change related to the origin of plants. Indigenous species comprised 63.4% of all species in 1969 but only 53.9% of the total in 2017. The proportion of introduced native species increased from 0.8% of all species in 1969 to 11.5% by 2017; all except two were dicots. The proportion of exotic species remained similar in 1969 and 2017 (35.0% and 33.5% respectively).

The main increase in the number of non-indigenous native species occurred after 1980 (see Table 9). Sources of these include the ANBG, where cultivated native Australian taxa have become naturalised in native bushland within its southern and western boundary fences, some species also naturalising in its southern and northern annexes and in adjacent parts of the nature reserve (Purdie 2014). These represent a small proportion of all species cultivated in the Gardens, and the majority of woody species cultivated there appear to have a low naturalisation potential (Purdie 2014). Cultivated areas in CSIRO, ANU and gardens in nearby urban areas such as Turner and O'Connor, visitors to the study area, and illegal dumping of garden waste (especially along Frith Road) are also potential or known sources of introductions. All non-indigenous native species within the study area that are thought to have originated from ANBG, and all landscaping species, were included in the final plant list because of their potential to spread into the adjacent nature reserve (if they had not already done so).

Although a focus of this study was attempting to relocate species with no verifiable record on Black Mountain for 30 or more years, an unexpected outcome was recording 93 additional species from late 2013, despite the large number of plants that had already been collected there (Purdie 2018a). The newly recorded plants included 39 introduced native species (including 10 used for landscaping), 35 exotics, 14 species considered to be indigenous to Black Mountain and five of uncertain origin. The increased number of indigenous species included only two relatively recently described taxa[6]. Ninety-four per cent of all species recorded since 2012, including all except one of the additional indigenous species (*Senecio diaschides*, Erect Groundsel), had a restricted or very restricted distribution in the study area, and the remaining species a sparse distribution. This suggests that most species were located only because of the intensive search effort from December 2013 to April 2017, even if they were present on Black Mountain prior to 2013. Weed species, including exotics and Australian natives, and species used for landscaping, often are not a priority for collecting, which may also help explain their absence in pre-2013 records.

The additional 93 species included some that were the first records of the taxa in the ACT. They included *Erigeron karvinskianus* (Seaside Daisy), *Lindsaea microphylla* (Lacy Wedge Fern), *Thomasia petalocalyx* (Paper Flower) and *Pomaderris discolor*. The first three species were clearly not indigenous to the study area. Seaside Daisy is an exotic herbaceous daisy. Lacy Wedge Fern is native to coastal areas of NSW and was growing on a man-made cutting along Black Mountain Drive, the spores possibly introduced there by a passing car. Paper Flower is a subshrub native to southern Victoria, South Australia and Western Australia that may have been used for landscaping near the mid-level car park off Black Mountain Drive and subsequently naturalised. The origin of the shrub *Pomaderris discolor* on Black Mountain is uncertain, and discussed in section 4.3.3 below.

[6] *Bulbine glauca* (Rock Lily), first collected in the study area in 2016, was described in 1987 (Watson 1987) as a separate species from *B. bulbosa* (Bulbine Lily) which is more widespread in the study area and first recorded there in 1935. *Chiloglottis seminuda* (Bare-tipped Wasp Orchid) was described in 1991 (Jones 1991) but first collected in the study area in 2014.

The 103 species with no herbarium or other verifiable record from Black Mountain since the end of 1980[7] that had not been relocated by the end of the study ('missing' species, Table 11) included four recorded in the 1930s, six recorded in the 1940s and 11 recorded in the 1950s, i.e. the most recent record of them was 63–82 years ago. Of the 64 species that could still be present (Category 9 in Table 11) 29 were exotic taxa (Appendix 4), all of which were forbs or grasses, most were annuals, and most had a sparse or restricted distribution and were locally common or not common. The grasses included agricultural weeds, such as *Bromus catharticus* (Prairie Grass), *Bromus inermis* (Awnless Brome) and *Dactylis glomerata* (Cocksfoot), that typically favour disturbed areas and originally were probably located in habitats associated with peripheral parts of the study area. The latter were the least searched during this study, especially along Parkes Way and the slip road to it from Caswell Drive. Forbs included environmental weeds such as *Eschscholzia californica* (California Poppy) and *Xanthium spinosum* (Bathurst Burr). The latter was recorded only in highly disturbed areas on the lower slopes of Black Mountain and was probably destroyed by roadworks, while California Poppy was recorded only from the former rubbish dump and, if it persisted, would have been eradicated when the dump was rehabilitated. Most of the 34 'missing' indigenous species (Appendix 4) were perennials with a sparse or restricted distribution, and some might still persist in the area. Possible support for the latter comes from the 14 newly recorded indigenous species (Table 8), most of which were perennials, most with a very restricted or restricted distribution, and most in locations and habitats that suggested they were unlikely to be recent introductions on Black Mountain.

According to the census of ACT flora (Lepschi et al. 2017) 11 of the 103 'missing' species are no longer considered to be present in the ACT (on the basis that no specimens have been collected from the ACT for at least 50 years), while three are categorised as formerly naturalised and one as doubtfully naturalised (see Appendix 4). These 15 species comprise 11 taxa in categories 1–3 in Table 11 (taxa no longer considered to be present in the study area) or categories 4–6 (taxa that lie outside the area), two Category 7 species (taxa associated with disturbed habitats), and two Category 9 species (taxa that might still be present). It is highly unlikely that these species (all exotic) will be relocated in the study area.

4.3 Black Mountain's current vascular flora: species recorded from 2007 to April 2017

Of the 593 species that comprise the current vascular flora (column 12 of Appendix 3), 56.3% are indigenous, 28.5% exotic and 14.0% non-indigenous natives while 1.2% are of uncertain origin (Table 12). Although some/all of the 28 species recorded from 1981 to 2006 (inclusive) may still be present, they were excluded from the current flora list as there was no verifiable record of them in the area over the last decade.

Thirty-seven species (6% of the current flora) have been recorded only within the ANBG northern and/or southern (Bush Precinct) annexes (column 12 of Appendix 3). Four indigenous species—*Grevillea ramosissima* (Fan Grevillea), a rare species in the ACT (Mulvaney 2018), *Wahlenbergia graniticola* (Granite Bluebell), *Cheilanthes distans* (Shaggy Rock Fern) and *Chiloglottis seminuda* (Bare-tipped Wasp Orchid)—have been recorded only in the Bush Precinct. The remaining 556 species have been recorded in Black Mountain Nature Reserve and adjacent roadside areas, many also within the ANBG annexes.

Approximately 44% of species are associated predominantly with dry sclerophyll forest, 18% with grassy woodland and associated derived grassland and 15% with creek lines, broad drainage flats and seepage areas (column 13 of Appendix 3). Around 22% of the total occur in highly disturbed areas (edges of roads, highways or walking tracks, road easements, picnic areas etc.); 92% of these are exotic, introduced native or landscaping species.

An overview of the current flora, and possible changes in the distribution and abundance of some species with a restricted/very restricted distribution in 1969 (see tables 15 and 16), are discussed in

[7] Excluding four species with good location data that were not relocated (see section 3.3.1).

the following sections.

4.3.1 Indigenous species

Indigenous species include 14 ferns, two conifers, 186 dicots and 132 monocots (Table 12). The ferns and conifers comprise less than 5% of the indigenous flora, but are a characteristic feature of the vegetation. The most widespread and common fern, *Cheilanthes sieberi* (Mulga Rock Fern), is generally associated with dry sclerophyll forest. Seven fern species are associated predominantly with a creek line running south-west from Black Mountain's summit, with three also associated with other creeks on the south side of the mountain. Two species generally grow on sheltered rock outcrops in dry sclerophyll forest, while one species (*Cheilanthes distans*, Shaggy Rock Fern) is restricted to rocky slopes in the ANBG southern annex. *Ophioglossum lusitanicum* (Austral Adder's Tongue) mostly occurs in soakage or damp grassland areas and only appears during seasonally wet conditions.

Of the two indigenous conifers, *Callitris endlicheri* (Black Cypress Pine) has a sparse distribution and its current abundance ranges from rare to locally common. The larger stands are located downslope of the Forest Trail on the north-west side of the mountain, south of the Orchid Track in the north-west, east of the Swamp Track on the western side of the reserve and along the Callitris Track near its junction with the Powerline Trail. Other small stands and isolated mature trees are also scattered over the north, west and south slopes of the area, originating from wind-blown seed either from Black Cypress Pine along the Murrumbidgee River (Coyne 1969) or local mature trees. Coyne (1969) recorded only two Black Cypress Pine stands on Black Mountain, each consisting of "a large tree surrounded by a cluster of younger progeny". This uneven-age structure typifies the four stands present today (see also Doherty 2018b). The additional two stands and the change in the species' abundance rating (from rare in 1969 to locally common in 2017, Table 15) suggest ongoing localised population recruitment since 1969, probably reflecting the continued absence of high intensity fires (Fraser 1981). Although its distribution rating changed from very restricted in 1969 to sparse in 2017, it is difficult to say if the species has become more widespread or was just observed in fewer locations in the 1960s. *Callitris glaucophylla* (White Cypress Pine) is known from a single old-growth tree in the north-west of the reserve. It is assumed to be indigenous to Black Mountain because the tree is comparable in size with the largest Black Cypress Pine trees there. Several smaller White Cypress Pine plants are located nearby on the north side of Belconnen Way on the lower southern part of Bruce Ridge.

The dicots (186 species) are the largest group of indigenous plants on Black Mountain. They include 96 forb, 45 shrub, 23 subshrub and 14 tree species. The five largest families are Asteraceae (37 species), Fabaceae (27 species, including 11 acacias), Myrtaceae (13 species) and Campanulaceae and Ericaceae (8 and 9 species respectively). Twenty-five species (13%) have a widespread distribution in the area, of which the three very common species (*Eucalyptus macrorhyncha*, Red Stringybark; *E. mannifera*, Brittle Gum; and *E. rossii*, Scribbly Gum) dominate the dry sclerophyll forest. Most of the other widespread species have an abundance rating from locally common to not common.

Ninety-seven dicot species (52%) have a sparse distribution, of which seven have a rare abundance rating and the remainder are not common to locally common. Forty-nine species (26%) have a restricted distribution, of which 13 are rare and the remainder more abundant (not common to locally common). Fifteen species (8%) have a very restricted distribution and include 13 with an abundance rating of rare or once collected.

The 132 monocots comprise 96 species of graminoids, 34 grass species and two aquatics. The five largest families are Orchidaceae (51 species), Poaceae (34 species) and Cyperaceae, Juncaceae and Asparagaceae (12, 11 and nine species respectively). Seventeen species (13%) have a widespread distribution, of which only one is very common, viz. *Rytidosperma pallidum* (Red-anthered Wallaby Grass); it is dominant in the ground layer over much of the dry sclerophyll forest. Forty-three species (33%) have a sparse distribution, most with an abundance rating of not common to locally common. Fifty-seven species (43%) have a restricted distribution, and include one (*Eleocharis atricha*, Tuber Spikerush) with a seasonally dependent very common abundance rating,

and 12 species (including six orchids) with a rare abundance rating. Twelve species (9%) have a very restricted distribution, and include five that have been collected only once and three orchids with a rare abundance rating.

Twenty-six species with a very restricted or restricted distribution in 1969 were assigned an increased distribution rating in 2017 (see tables 15 and 16). They include eight shrubs, seven forbs, three grasses and six graminoids (including five orchids). One tree (*Allocasuarina verticillata*, Drooping Sheoak) and one shrub (*Kunzea parvifolia*, Violet Kunzea) species changed from very restricted in 1969 to restricted in 2017 (Table 15). The former has a small number of widely scattered individual plants now present in the area, while the latter occurs in at least 12 widely separated locations on the north side of the reserve, mostly as solitary, very old plants. The very restricted distribution rating of both species in 1969 may just indicate that not all occurrences were observed at that time. The distribution of *Acacia penninervis* (Mountain Hickory) changed from very restricted in 1969 to sparse in 2017 (Table 15). Its change in distribution and abundance (from not common to locally common) may reflect incidence of fires in the area in the last decade or so. The other six shrub species changed from a restricted distribution in 1969 to a sparse distribution in 2017 (Table 16). Of these, *Hakea decurrens* (Bushy Needlewood), *Olearia microphylla* (Twiggy Daisybush), *Choretrum pauciflorum* (Dwarf Sourbush) and *Omphacomeria acerba* (Leafless Sourbush) may have become more widespread since 1969: the first two have wind-borne seeds and the latter two succulent fruit probably dispersed by birds.

The apparent increased distributions of the 16 herbaceous species between 1969 and 2017 is probably an artefact that reflects how easy it is to overlook them in the vegetation. For the five orchid species (*Acianthus exsertus*, Large Mosquito Orchid; *Caladenia caerulea*, Blue Caladenia; *Corunastylis clivicola*, Rufous Midge Orchid; *Diplodium revolutum*, a greenhood; *Pterostylis nutans*, Nodding Greenhood), it probably also reflects the greater number of enthusiasts now visiting the area specifically to locate orchids (Purdie 2018c). During the 2013–2017 field work, the forb *Senecio bathurstianus* (Bathurst Fireweed) was observed in several parts of Black Mountain that had been subject to recent fuel reduction burns; its restricted distribution in 1969 (Table 16) may thus reflect lack of recent burns at that time. The changed distribution of the forb *Daucus glochidiatus* (Australian Carrot; Table 16) most likely reflects the inclusion of the south-west grasslands only in the current study area.

4.3.2 Non-indigenous native species

The 81 native species not indigenous to Black Mountain include 31 taxa used just for landscaping and another 50 adventive species, two of which have also been used for landscaping (Table 12). Nineteen of the 33 landscaping species (58%) have naturalised.

Acacia is the largest genus of native weeds in the area, and of the 27 species currently part of the flora, 12 have probably escaped from ANBG. These include *A. extensa* (Wiry Wattle), *A. falcata* (Hickory Wattle), *A. flexifolia* (Bent-leaved Wattle), *A. saligna* (Blue-leaved Wattle), *A. sertiformis*, *A. stricta* (Hop Wattle) and *A. viscidula* (Sticky Wattle) that were found only within or near the ANBG northern annex. Except for Wiry Wattle and Blue-leaved Wattle, that both had large, multi-age populations, all other species occurred in low numbers. Species such as *A. elata* (Mountain Cedar Wattle), *A. binervata* (Two-veined Hickory) and *A. howittii* (Howitt's Wattle), that were present as sporadic plants only on the eastern side of Black Mountain, are also assumed to have escaped from ANBG.

The most widespread and abundant non-indigenous shrubs in the study area are *Acacia baileyana* (Cootamundra Wattle), *A. decurrens* (Green Wattle) and *A. rubida* (Red-leaved Wattle). All three were recorded as adventive to the area by Gray and McKee (1969), and the first two are rated highly invasive species in the ACT (Berry and Mulvaney 1995). Old, mature Cootamundra Wattle plants are scattered in many parts of the reserve, their soil-stored seeds generating hundreds of seedlings after fire (Purdie unpublished). The distribution ratings for Red-leaved Wattle suggest it is now more widespread, changing from a very restricted distribution in 1969 to a sparse distribution in 2017 (Table 15). The introduced native *Cassinia sifton* (Chinese Shrub) was also recorded by Gray and McKee (1969) although at that time it was called *C. arcuata* and considered indigenous to the

study area. Despite being a woody weed in many parts of NSW (Orchard 2017), its distribution rating on Black Mountain only increased from rare in 1969 to sparse in 2017.

Since 1969 *A. cultriformis* (Knife-leaved Wattle), a species often cultivated in urban gardens and used for landscaping, has also become relatively widespread in the study area and locally common in some places. At least three other species occurring sporadically within the reserve (*A. boormanii*, Snowy River Wattle; *A. fimbriata*, Swamp Wattle; *A. vestita*, Weeping Boree) have probably been introduced by birds from nearby urban gardens, reflecting the increased use of native plants in horticulture from the 1970s. Knife-leaved Wattle, *A. dawsonii* (Poverty Wattle) and *A. subulata* (Awl-leaved Wattle) have all been used for landscaping along Belconnen Way where they have naturalised, the former two into the reserve. A small population of *Acacia lunata* (Lunate-leaved Wattle) near the footprint of Telstra Tower was probably introduced during earth works associated with its construction.

The 33 landscaping taxa occur mostly along Barry Drive, Belconnen Way, Parkes Way and in the car park and picnic areas halfway up Black Mountain Drive, and all except one have a restricted to very restricted distribution. Of the 18 species that have naturalised into adjacent areas, five are locally common (*Melaleuca armillaris*, Bracelet Honey Myrtle; *M. parvistaminea*, Rough Paperbark; *Hakea eriantha*, Tree Hakea; *H. salicifolia*, Willow-leaved Hakea; *H. sericea*, Needlebush), two are rated not common (*Darwinia citriodora*, Lemon-scented Darwinia; *Grevillea juniperina* subsp. *sulphurea*) and the remainder are rare. *Grevillea rosmarinifolia* (Rosemary Grevillea) has a sparse distribution in the study area and an abundance rating of not common; widely scattered adventive individuals occur on the eastern side of Black Mountain. Most of the remaining introduced native species have a restricted to very restricted distribution in the study area. An exception is *Billardiera heterophylla* (Bluebell Creeper), that has a sparse distribution and is often locally common. It is cultivated in both ANBG and adjacent urban areas, has bird-dispersed fruit and is highly invasive in the ACT (Berry and Mulvaney 1995).

The 2017 distribution and abundance ratings of the introduced native species recorded in Appendix 3 reflect their presence in the study area prior to recent removal efforts (Beveridge 2018). The extent to which the current ratings of Cootamundra Wattle, Green Wattle and Red-leaved Wattle reflect active management between 1969 and 2014 is not known.

4.3.3 Native species of uncertain origin

Seven species currently on Black Mountain are of uncertain origin (Table 12). *Olearia erubescens* (Silky Daisybush), first collected in the area in 1953, is native to the ACT (Lepschi et al. 2017), where it is otherwise known from higher altitudes in the Brindabella Ranges. Black Mountain is the only known location of *Daviesia acicularis* (Sandplain Bitterpea) in the territory, with one collection in 1959 from its lower east slopes and another in 2014 between Frith Road and the ANBG boundary fence. The closest locations of this species to Black Mountain are north-east of Lake George and east of Bungendore near Boro. Both species have been cultivated in ANBG.

The other five species (two ferns and three shrubs) were only recorded in the study area later than 2012. The ferns *Doodia australis* (Rasp Fern) and *Cyathea australis* (Soft Treefern) are both native to the ACT (Lepschi et al. 2017), although their habitats are generally moister than on Black Mountain where they occur together on the upper slopes near the south-west creek. This habitat and their location just below Black Mountain Drive suggests they could be sourced from dumped garden rubbish, although the two metre height of the largest Soft Treefern plant indicates it has been there for a long time. The shrub *Ozothamnus diosmifolius* (Rice Flower) is known from only a few locations in the ACT, including Mount Ainslie and a solitary plant upslope of the Kids Lookout Trail on Black Mountain. It is a widely cultivated species with wind-dispersed seed and may not be indigenous to the study area. The shrub *Pomaderris angustifolia* (Narrow-leaved Pomaderris) is native to the ACT (Lepschi et al. 2017), common along the Molonglo and Murrumbidgee rivers and also recorded from Mount Ainslie. On Black Mountain, its location in disturbed native vegetation below power lines near Frith Road suggests it could have been introduced there. The shrub *Pomaderris discolor* is native to eastern Australia, with its closest occurrence to Black Mountain located in Monga National Park, south-west of Braidwood. Although the species has

been cultivated in ANBG, the species' location in the study area makes it unlikely that ANBG was its source.

4.3.4 Exotic species

The exotic flora in the study area comprises two conifer, 128 dicot and 39 monocot species. Both the conifers, *Pinus radiata* (Radiata Pine) and *Hesperocyparis arizonica* (Arizona Cypress), have a very restricted distribution. Coyne (1969) noted that Radiata Pine had naturalised half way up the eastern slopes and other isolated parts of the reserve by 1969. It now occurs as widely scattered individuals, although the presence of sawn dead trunks on the ground in some parts of the reserve show where it was more common in the past. Arizona Cypress is only known from two mature plants, one in the ANBG northern annex and the other in a gully-head on the eastern side of the mountain.

The exotic dicots comprise four climbers, 94 forbs, 21 shrubs, one subshrub and at least eight tree species. Most of the tree species have a restricted to very restricted distribution, and a rare abundance rating (except for *Fraxinus angustifolia* (Desert Ash) which is locally common on the lower eastern slopes of the study area). *Celtis australis* (Lote Tree) has a sparse distribution, and occurs as single plants in widely separated locations, mostly on the east and south slopes. Its very restricted distribution rating in 1969 compared with sparse in 2017 (Table 15) suggests it may have become more widespread, however because its abundance rating was rare in both years, these differences may just reflect greater search effort in 2013–2017. In contrast, the climber *Lonicera japonica* (Japanese Honeysuckle) has probably become more widespread (from very restricted in 1969 to sparse in 2017; Table 16); it was recorded as locally common in both years and is not easily missed. The other three climbers have a restricted to very restricted distribution and an abundance rating of rare or once collected; none was recorded in the area prior to 2013.

The 22 shrubs and subshrubs include 11 species from the Rosaceae, mostly in the genera *Cotoneaster*, *Crataegus*, *Pyracantha*, *Rosa* and *Rubus*. The four most widespread species, *Berberis aquifolium* (Mahonia), *Crataegus monogyna* (Hawthorn), *Rosa rubiginosa* (Sweet Briar) and *Rubus anglocandicans* (Blackberry), have a sparse distribution and are either rare (Mahonia) or locally common. Hawthorn and Blackberry may have become more widespread between 1969 and 2017, from restricted to sparse (Table 16). Ten species have a very restricted distribution and all except one is rare or once collected. The remaining eight species all have a restricted distribution and are rare or not common except for the locally common *Pyracantha angustifolia* (Orange Firethorn). *Ligustrum sinense* (Chinese Privet) may have become more widespread since 1969 (Table 15): it had a distribution/ abundance rating of very restricted/once collected in 1969 and restricted/rare in 2017.

Species such as Blackberry, Chinese Privet, Japanese Honeysuckle, Lote Tree, *Genista monspessulana* (Montpellier Broom), *Robinia pseudoacacia* (Black Locust) and *Pyracantha* spp. (firethorns) are all environmental weeds or species with a high weed potential in the ACT (Berry and Mulvaney 1995). Although present in the study area in 1969, they were mostly recorded in localised areas currently. Japanese Honeysuckle, Blackberry and Firethorn are well-established only in localised moister habitats, Honeysuckle on the shaded lower parts of the steep south-facing slope above Parkes Way, Blackberry mostly in disturbed areas near Parkes Way on the lower south slopes, incised creeks on the lower south-west slopes, and broad drainage lines on the north side near Belconnen Way, and Firethorn on moist lower slopes in the south-east. They occur only sporadically in other parts of the study area, in relatively undisturbed dry sclerophyll forest that presumably provides less suitable habitats. Lote Tree and Chinese Privet plants are today very sparsely distributed, usually in more shaded/sheltered locations in dry sclerophyll forest. Species such as Montpellier Broom and Black Locust that were only recorded near roads may have been one-off adventive occurrences, the individuals dying before reproducing and/or being destroyed by roadworks.

Forbs comprise 56% of the exotic species, and include 20 daisies (Asteraceae), 11 pea flowers (Fabaceae) including seven clovers (*Trifolium* spp.) and 11 species in the Caryophyllaceae. Three species, *Hypochaeris radicata* (Flatweed), *H. glabra* (Smooth Catsear) and *Centaurium erythraea*

(Common Centaury), are widespread and common to fairly common. Twenty-eight species have a sparse distribution; one (*Tolpis barbata*, Tolpis) is common, 17 locally common and the rest not common. Of the 49 species with a restricted distribution, 20 are locally common and the remainder not common to rare. Fourteen species have a very restricted distribution and, apart from the locally common *Physalis hederifolia* (Sticky Cape Gooseberry), are either rare or once collected. *Hypericum perforatum* (St John's Wort), a recognised environmental weed, has a sparse distribution and is locally common.

Exotic grass species in the study area include the highly invasive perennials *Nassella neesiana* (Chilean Needlegrass), *N. trichotoma* (Serrated Tussock) and *Eragrostis curvula* (African Lovegrass). The first herbarium records of Chilean Needlegrass are from two specimens in 1961–62 on the eastern side of Black Mountain. It currently occurs as small populations along Black Mountain Drive, Frith Road and its extension, and in the road easement above Parkes Way in the south-east (where spread upslope may be prevented by adjacent extremely dense stands of *Kunzea ericoides*, Burgan). The earliest record of Serrated Tussock was in Smith's Paddock in the early 1980s (Pavlovic 1982). Isolated small populations are still present there and also occur along Black Mountain Drive, Frith Road and its extension, as well as in the ANBG Bush Precinct and along the Powerline Track in the north. The first herbarium record of African Lovegrass was in the adjacent CSIRO grounds in 1975. It currently occurs sporadically on Black Mountain Drive, Frith Road and its extension, Barry Drive and Caswell Drive. Annual grasses typical of agricultural areas, such as *Bromus diandrus* (Great Brome) and *Bromus hordeaceus* (Soft Brome) were collected in the study area in the mid-1930s and recorded as common ruderal species in the grounds of CSIRO in the 1960s. Their current distribution in the study area is sparse (compared to sparse and widespread respectively in 1969) and their abundance not common (compared with locally common and common respectively in 1969).

Like the introduced native shrubs (section 4.3.2), the 2017 distribution and abundance ratings of the exotic woody species (Appendix 3) reflect their presence in the study area prior to recent volunteer woody weed removal (Beveridge 2018). The ratings for invasive herbaceous species, such as St John's Wort and perennial grasses, take account of recent targeted control work (ACT Government unpublished). The extent to which the current ratings of woody and herbaceous exotics reflect active management prior to 2012 is not known.

4.4 General comments

4.4.1 Using censuses to measure change

Detailed knowledge about any area's flora provides an essential framework for conserving its plant diversity and for management actions such as weed control and fire/fuel management. This study highlights the search effort that can be required to obtain a comprehensive, up-to-date census of vascular plant species in an area. Transects and/or plots used for vegetation monitoring on Black Mountain (Purdie 2018c) are likely to provide information on the presence and/or abundance of the 8% of species that are widespread in the study area (see section 3.4.1) but miss many of the 57% of species with a restricted or very restricted distribution. The study also demonstrates the value of censuses supported by herbarium specimens (as verifiable records of species) in providing benchmarks to assess changes in an area's flora, particularly in relation to the incursion of non-indigenous species.

A major limitation of this study was the inability to track species that may have become locally extinct. This was largely the result of the very general location data on many herbarium specimens, and many species having a restricted or very restricted distribution. There were data to suggest with confidence that four indigenous and three exotic species have become locally extinct in the study area (section 3.3.1), but it was not possible to determine whether another 64 taxa (Category 9 species in Table 11) are still present or not. While it appears that at least some may still persist on Black Mountain (section 4.2), relocation of them probably requires a very intensive systematic grid search (cf the random meander search used in this study, see section 2.2), as well as the searcher being present in the right location during the right environmental conditions at the right time for species to be identifiable. It is possible that at least some of these taxa originally may have occurred

outside the current study area in the more extensive Black Mountain and environs area of Gray and McKee (1969) (Fig. 1a). The latter has not been searched for the species, although positive records there would not necessarily mean absence from Black Mountain itself.

Temporal changes in abundance are difficult to assess because they are affected by so many variables (section 4.2). Broad abundance ratings for a large area may also mask important local changes. For example, the detailed species list of Pavolvic (1982) for a research site in Smith's Paddock did not include Burgan although it now dominates the area and presumably has been introduced there from wind-born seed. That type of change is not reflected in Burgan's abundance rating over the study area, from common in 1969 to locally common by 2017. While the abundance of species on Black Mountain has been measured accurately by counting individuals or estimating percent canopy cover in defined plots (e.g. Murray and Lepschi 2004; Purdie 2018c), these techniques are impractical for covering every species across the whole area.

4.4.2 Species richness

Knowledge of Black Mountain's vascular plants is now comprehensive, but it is difficult to compare its species richness[8] with similar vegetation elsewhere, either because studies are plot-based and/or have involved much less search effort. Armstrong et al. (2013) described three dry sclerophyll forest community types in the local region similar to that on Black Mountain, each including the latter's three widespread dominant trees (Brittle Gum, Red Stringybark and Scribbly Gum). However, the mean richness of native species for each community type, measured by thorough searches within 20 m × 20 m plots (Table 17), is not directly comparable with the Black Mountain study area, which relates to all species in a 500 ha area. From its distribution, community p14 would encompass Black Mountain's dry sclerophyll forest, but at least 20 of the 68 species characterising the community do not occur on the latter.

Table 17. Native species richness of regional dry sclerophyll forest vegetation similar to that on Black Mountain (Armstrong et al. 2013)

Dry sclerophyll forest community type	General location	No. of samples	Richness: mean no. spp./0.04 ha	Characteristic spp.	
				Total number	No. absent from Black Mtn
m51: Brittle Gum – Scribbly Gum shrub-grassland tall dry sclerophyll forest on exposed quartz-rich slopes and ridges.	South-east of Canberra in Monaro and Kybeyan–Gourock areas	50	21±7	29	4
p9: Brittle Gum – Scribby Gum shrubby tall dry open forest on infertile low ridges and hills.	East and north-east of Canberra, mostly in the Bungonia area	51	30±8	39	7
p14: Red Stringybark – Scribby Gum – *Rytidosperma pallidum* tall grass-shrub dry sclerophyll open forest on loamy ridges.	North-eastern ACT and north-east of Canberra, in the central South Eastern Highlands	165	27±8	68	20+

[8] Species richness is commonly defined as either the total number of species present in an area or the number of species per unit area (e.g. species per hectare).

The current study is more comparable to that of Lepschi (1993) for Mulligans Flat, ACT and of Hadobas and Hadobas (2018) for a property near Boro, NSW, as both involved intensive, targeted, repeated search effort (Lepschi for all species; Hadobas and Hadobas for native species). The Mulligans Flat vegetation is similar to that on Black Mountain but far less dry sclerophyll forest is present (Lepschi 1993). The total number of species recorded on Black Mountain and the total number of species per hectare are higher than those recorded for Mulligans Flat, but both areas have a similar number of native species per hectare (Table 18). Eight-seven per cent of native species recorded at Mulligans also occur on Black Mountain.

The number of native species on the Boro property exceeds that of Mulligans Flat and is slightly lower than Black Mountain's, but its native species density (1.4 species/ha) is approximately twice as high as the latter two areas (Table 18). The Boro property shares only 60% of its native species with Black Mountain (that lies approximately 53 km to the west) and although its dry sclerophyll vegetation includes Brittle Gum and Scribbly Gum, it lacks Red Stringybark. Much of Mt Ainslie – Mt Majura is covered in dry sclerophyll vegetation similar to Black Mountain's, and it shares 88% of its native species with it. However, the total number of species and the native species density of Ainslie–Majura are both much lower than Black Mountain's (Table 18). These differences likely reflect the much lower plant collecting effort on Ainslie–Majura (450 herbarium specimens cf c.3300 specimens for Black Mountain) and the opportunistic nature of many Canberra Nature Map records. The 33 species absent from Black Mountain possibly reflect differences in underlying geology (volcanics on the former and sandstone on the latter; Abell 2007).

Table 18. Comparison of plant species richness in Mulligans Flat, Mt Ainslie – Mt Majura, a private property near Boro, NSW and Black Mountain

	Mulligans Flat[a]	**Mt Ainslie – Mt Majura**[b]	**Boro property**[c]	**Black Mountain**[d]
Total area (ha)	275	1121	248	500
Total species/ha	1	0.4		1.5
Native species/ha	0.7	0.2	1.4	0.8
Total number of species in area	276	415		728
- native species	180 (65%)	270 (65%)	347	393 (54%)
- introduced species	96 (35%)	141 (34%)		327 (45%)
% fern species	1	3		3
% conifer species	<1	1		<1
% monocot species	30	25		30
% dicot species	69	72		66
Main geology	Mudstone and siltstone	Volcanics	Granite	Sandstone

[a] Lepschi (1993).
[b] Area from http://www.environment.act.gov.au/parks-conservation/parks-and-reserves/find-a-park, accessed 5/12/17; species data from ANHSIR and Canberra Nature Map records, 13 January 2018; geology from Abell (2007).
[c] Area and geology from Hadobas and Hadobas (2018); species data from ANHSIR records, 15 January 2018.
[d] Area from section 2.1 and species data from Table 5 of this study; geology from Abell (2007).

The above analyses suggest that although Black Mountain has a high total number of species recorded from it, the number of species per hectare is not unusually high in the ACT context[9]. The high total number appears to reflect high search effort rather than high intrinsic floristic richness;

[9] This also holds if Black Mountain's current flora is used in the analyses.

high search effort inevitably skews data to the 'high end' of total species count, but thereby provides a more accurate measure of it. This is echoed in Black Mountain's orchid richness: although it has the highest recorded number of orchid species of all the ACT's orchid 'hot spot' locations, both Aranda Bushland and Bruce Ridge have a higher number of orchid species per hectare (Table 19).

Table 19. Number of orchids recorded in selected orchid-rich locations in the ACT[a] to 2008 and 2018

Location	Number of species recorded to 2008[b]	Number of species recorded to 2018[c]	Area (ha)	Species/ha
Aggie Gap	10			
Aranda Bushland	25	45	104[f]	0.43
Black Mountain	61	61[d]	500	0.12
Booroomba Rocks	20			
Bruce Ridge	12	16	94[g]	0.17
Bulls Head	11			
Fishing gap	10			
Gibraltar Falls	21			
Gungahlin Hill	14			
Majura Firing Range	17			
Mt Ainslie – Mt Majura	12	34[e]	1121[g]	0.03
Mt Gingera	14			
Mt Ginini	20			
Mt Taylor	10	22	297[g]	0.07
Mt Tennent	17			
Mulligans Flat	12			
Smokers Flat	11			
Smokers Gap	13			

[a] From named locations in Jones et al. (2008) with ≥10 species, excluding extensive or poorly defined areas such as Brindabella Range, Tidbinbilla, Bendora Dam Road etc.
[b] Data from places listed under Local Distribution heading in Jones et al. (2008).
[c] Data from Canberra Nature Map records for locations with a Nature Park map, 11 January 2018.
[d] Data from Appendix 3 of this report, including Canberra Nature Map records.
[e] Data from ANHSIR and Canberra Nature Map records, 11 and 13 January 2018.
[f] Data from M Mulvaney, ACT Government.
[g] Data from http://www.environment.act.gov.au/parks-conservation/parks-and-reserves/find-a-park, accessed 5 December 2017.

Jones et al. (2008, page 6) commented that the ACT is "relatively orchid rich" compared with many other parts of Australia, comprising about 12% of the ACT's native flora but only 5–6% of the Australian flora. To some extent this reflects the high search effort for orchids in the territory and Jones' high taxonomic output. Of the 118 orchid species listed in the ACT Plant Census[10] (Lepschi et al. 2017), 56 (48% of the total) have been described since 1969, 49 of them in the 1990s and 2000s; 51 of the species were described by Jones (a few jointly with colleagues). Twenty-four species recorded on Black Mountain have been described since 1969 (one, three, seven and 13 species respectively in the 1970s, 1980s, 1990s and 2000s), all by Jones (including three jointly

[10] This figure excludes two undescribed species and two hybrids.

with Clements). The higher number of species recorded in Canberra Nature Map to 2018 (compared with those to 2008 except for Black Mountain) reflects the greater search and recording effort by numerous local orchid enthusiasts since the Map was established, with search effort in other parts of Canberra Nature Park now more similar to that of Black Mountain.

4.4.3 Species diversity and fire management

Two tree and 16 shrub species that are part of Black Mountain's current indigenous flora are, or may be, fire sensitive, i.e. the plants are killed by fire and the species rely on post-fire seed germination to persist locally (see Doherty 2018b). While three of the species are widespread in the study area and often dominant in the shrub layer (Table 20), six species have a sparse distribution, four species a restricted distribution and five species a very restricted distribution. The latter include *Grevillea ramosissima*, a rare species in the ACT (see Mulvaney 2018) that is locally common on Black Mountain. Three of the remaining species with a very restricted distribution have an abundance rating of once collected and are represented by only 1–6 individuals. All these fire sensitive species require sufficient time between burns (whether wildfires or fuel reduction burns) for plants to reach sexual maturity and replenish their soil or canopy seed banks to ensure they remain part of the area's floristic diversity.

Table 20. Indigenous tree and shrub species killed by fire and reliant on seed germination for post-fire regeneration (i.e. fire sensitive)

Family	Species	Distribution rating	Abundance rating
Cupressaceae	*Callitris endlicheri*	Sparse	Locally common
Cupressaceae	*Callitris glaucophylla*	Very restricted	Once collected
Fabaceae	*Acacia genistifolia*	Widespread	Common
Fabaceae	*Dillwynia phylicoides*	Widespread	Common
Fabaceae	*Dillwynia sericea*	Sparse	Locally common
Myrtaceae	*Calytrix tetragona*[a]	Restricted	Locally common
Myrtaceae	*Kunzea parvifolia*[a]	Restricted	Not common
Proteaceae	*Grevillea alpina*	Widespread	Common
Proteaceae	*Grevillea ramosissima* subsp. *ramosissima*	Very restricted	Locally common
Rhamnaceae	*Pomaderris andromedifolia* subsp. *confusa*[a]	Restricted	Locally common
Rhamnaceae	*Pomaderris angustifolia*[a]	Very restricted	Rare
Rhamnaceae	*Pomaderris betulina* subsp. *actensis*[a]	Restricted	Locally common
Rhamnaceae	*Pomaderris discolor*[a, b]	Very restricted	Once collected
Rhamnaceae	*Pomaderris eriocephala*[a]	Very restricted	Once collected
Rhamnaceae	*Pomaderris intermedia*	Sparse	Locally common
Santalaceae	*Choretrum pauciflorum*[a]	Sparse	Not common
Sapindaceae	*Dodonaea viscosa* subsp. *spatulata*	Sparse	Fairly common
Thymelaeaceae	*Pimelea linifolia*	Sparse	Not common

[a] These species are known or thought to be fire sensitive elsewhere (e.g. the Sydney area; see Benson and McDougall (2000) for the *Pomaderris* species) and may be fire sensitive on Black Mountain.

[a] Although the origin of *Pomaderris discolor* on Black Mountain is uncertain (see section 4.3.3) the plants are being retained in the vegetation.

4.4.4 Weed persistence and management

The 169 exotic species that are part of the current flora (Table 12), most of which were present in 1969, are currently located predominantly around the periphery of the study area or in localised sheltered habitats in its interior (section 4.3.4). Although environmental weeds (such as Blackberry, Hawthorn, Japanese Honeysuckle, firethorns, St John's Wort, African Lovegrass, Chilean Needle Grass and Serrated Tussock) have been subject to active eradication programs in recent years (Fig. 2), the extent to which they were targeted previously is not known. However, the current peripheral locations where such weeds occur and/or are most abundant today are close to introduction sources (e.g. roads) and/or subject to high disturbance levels (e.g. from the maintenance of roads and powerline easements). These attributes make such areas prone to weed invasion. The sporadic presence of these species in the dry sclerophyll forest covering most of Black Mountain suggests this may be partly because of lack of regular disturbance. The extent to which the forest's soil properties (such as fertility and moisture retention) make these habitats unsuitable for environmental weeds is not known.

Perennial exotic environmental weeds such as Hawthorn, Serrated Tussock and St John's Wort currently occur in the south-west grassland/grassy woodland vegetation. Information about their past distribution, abundance and possible control there is lacking, although they have been subject to active management in recent years (Beveridge 2018; ACT Government unpublished). However, other major weeds do not appear to have invaded the area in the last 35 years. In the early 1980s the grassland research site in Smith's Paddock (Pavlovic 1982) was dominated by *Themeda triandra* (Kangaroo Grass) and other perennial indigenous species, with the soil seed bank dominated by Kangaroo Grass and mostly exotic annual taxa. Today the site has a healthy sward of Kangaroo Grass and the perennial *Bothriochloa macra* (Redleg Grass), with a large number of other perennial indigenous species seasonally present (Purdie unpublished). Annual exotic weeds, including those recorded by Pavlovic, are seasonally abundant, but were never dominant during the current study. Although the ratio of indigenous to exotic grassland herbaceous species recorded by Pavlovic was 1.9, slightly higher than the current ratio of 1.6 for the whole south-west grassland area recorded by Purdie (unpublished), the latter reflects an increased number of exotic species which are not considered to be environmental weeds and most of which are associated just with walking or vehicle tracks and a cycleway.

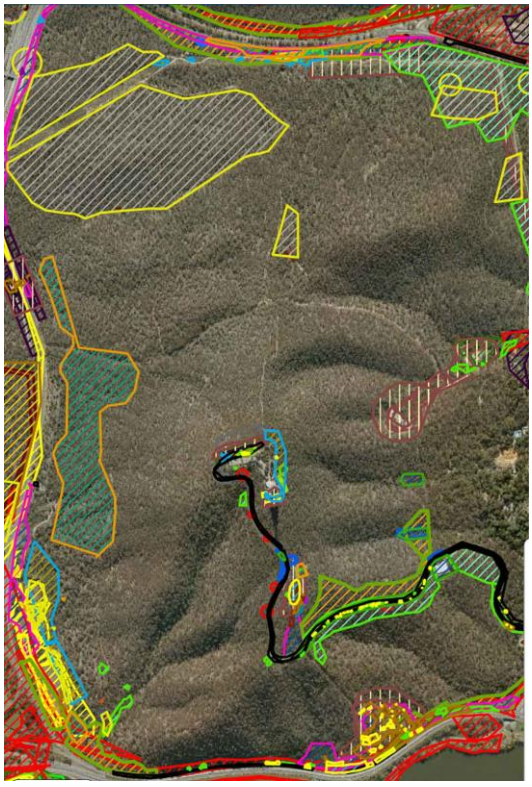

Fig. 2. Areas on Black Mountain where environmental weeds have been removed by the ACT Parks and Conservation Service, 2008–2018. Source: Steve Taylor, Senior Weed Management Officer, ACT Government.

The large increase in the number of introduced native species in the study area, from six in 1969 to 84 in 2017 (Table 9) presents a major management issue, especially the native woody weeds that have naturalised and are now more abundant and widespread than any exotic woody species except Blackberry. Most of these non-indigenous natives had naturalised from plantings in ANBG or were used for landscaping major roads (section 4.3.2), reflecting the culture at the time they were constructed.

Priority areas for management of all woody weeds (exotic and introduced native) are the disturbed road verges and peripheral areas of the reserve where many species are widespread and abundant (FoBM unpublished), and the interface with ANBG. To help minimise native species naturalising from the latter, Purdie (2014) recommended that the managers continue to retain the natural sections of the Gardens adjacent to the reserve as buffer areas where no new plantings are made and extant cultivated plants are considered for removal, and implement an ongoing, regular weed removal program in the buffer and nearby natural areas of the Gardens, targeting both native and exotic weed species. From June 2014 to December 2017, the Friends of Black Mountain removed around 12,600 woody weed plants from the study area, 91% of them from introduced native species (Beveridge 2018). Seeds remaining in the soil will provide an ongoing source for new plants, probably over decades to come for species such as *Acacia baileyana* (Cootamundra Wattle), *A. decurrens* (Green Wattle) and *A. rubida* (Red-leaved Wattle). Ongoing monitoring will be necessary to detect and remove newly germinated plants (especially after fuel reduction burns) and new incursions (mainly through bird or wind-dispersed seeds and fruit) likely to continue from ANBG and adjacent suburbs.

4.4.5 Managing over the next 50 years

The current focus of woody weed management—to remove any species considered not indigenous to the study area—is based largely on maintaining or improving the condition/integrity of the native vegetation. However, in the context of global warming, including the likelihood of novel plant assemblages developing in response to environmental change (Hobbs et al. 2018), this approach may not be the most appropriate for the next five decades, especially if building the resistance and resilience of the existing vegetation (Prober et al. 2012) warrants emphasis in the short- to medium-term.

The 'sharp end' of this issue is illustrated by the difficulty in determining whether some species recorded in the study area are introduced (and therefore removed) or indigenous (and therefore retained), which in turn depends on the definition of indigenous (in this study taken to be species that have not been introduced by humans or because of human activities, see section 2.3.3). *Bedfordia arborescens* (Tree Blanketleaf) was treated as indigenous to Black Mountain because of its location on the south-west side of the reserve and the possibility of seed being transported there by wind from plants growing naturally in the Brindabella Range to the west. *Brachychiton populneus* (Kurrajong) was treated as an introduced native because its seed were most likely introduced by birds eating the seeds of plants cultivated in ANBG or CSIRO or planted/naturalised on Mt Majura, even though the species is native elsewhere in the ACT. *Thomasia petalocalyx* (Paper Flower), which occurs naturally in southern Australia, was also treated as an introduced native because the plants from which it originated must have been introduced by people. Eight species that occur naturally in the wider Canberra region were assigned an uncertain origin (section 3.1 and Table 5) because there was no way of knowing whether they had been introduced with human intervention (direct transport by people, or wind- or bird-dispersed seed from cultivated plants in nearby suburbs) or without it (by long-distance wind or bird transport from naturally occurring populations).

Definitions such as those suggested by Gilroy et al. (2017)[11] would result in Kurrajong and six of the above eight uncertain species (those for which direct introduction by humans is improbable)

[11] Species would be non-native (i.e. not indigenous to an area) if transported outside their native range by direct human transport; species would be native (indigenous) if "moving via unassisted dispersal", even if they are "responding indirectly to anthropogenic change".

being designated as indigenous to the study area. For species introduced there without direct human transport from plants occurring naturally in the ACT (or the broader ACT region such as the NSW Southern Tablelands), a key question is whether or not treating them as part of the indigenous flora of Black Mountain would help build resilience in its vegetation. Further discussion around this issue is warranted to guide future woody weed management in the study area.

Black Mountain is unusual in having 1969 and 2017 benchmarks for recording changes in its floristic diversity. The accurate coordinates of plant locations on herbarium collections associated with this study will support future targeted searches for the many species with very localised distributions and/or low abundance. That information and the methods outlined in this paper should facilitate benchmarking that requires lower search effort and generates data more comparable with this 2017 census to assess floristic trends in the future.

5. Acknowledgements

Thanks to Mark Clements, Tony Wood and Jean Egan for their ready responses to queries about Black Mountain's orchids; to Brendan Lepschi for queries on plant nomenclature; to Aaron Clausen and Michael Mulvaney for providing data from Canberra Nature Map; to Michael Mulvaney for discussions about the origin of several species; and to Isobel Crawford, Michael Doherty, Richard Groves, Brendan Lepschi and Michael Mulvaney for comments on early drafts of this paper.

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Appendix 1

Excluded species: dubious identifications or name changes

The following species were excluded either because of a dubious identification or because of a taxonomic name change. Reasons are shown in the right-hand column.

Family	Scientific Name	Reason for exclusion
Asteraceae	*Brachyscome aculeata*	Reported in Department of the Capital Territory (1980) but record not supported by voucher specimen. Assumed to be a mis-identification of *B. spathulata*.
Asteraceae	*Craspedia canens*	Species not considered to occur in the ACT (Schmidt-Lebuhn and Milner 2013). Assumed to be a mis-identification of *C. variabilis*.
Campanulaceae	*Lobelia gibbosa*	Specimens re-determined as *L. browniana*.
Cyperaceae	*Isolepis australiensis*	Gray and McKee (1969) voucher specimen not located; species does not occur in the ACT or the NSW Southern Tablelands; assume mis-identification.
Cyperaceae	*Isolepis inundata*	Specimen re-determined to *Isolepis gaundichaudiana*.
Cyperaceae	*Lepidosperma latens*	Specimen is *L. laterale* but was originally listed in ANHSIR as *L. latens* due to a data-entry error.
Dicksoniaceae	*Calochlaena dubia*	Original record was from Canberra Nature Map, but no plants of this species were located by RW Purdie despite extensive searches in the reported location; assume mis-identification.
Dilleniaceae	*Hibbertia stricta* (formerly called *H. riparia*)	All Black Mountain specimens originally called *H. riparia* are *H. calycina* (Toelken 2016).
Ericaceae	*Epacris microphylla* var. *microphylla*	High altitude species in the ACT; assume mis-identification.
Fabaceae	*Daviesia leptophylla*	All sites where species was recorded were checked by RW Purdie but no *D. leptophylla* located (only the narrow-leaf form of *D. mimosoides*); assume mis-identification.
Hypoxidaceae	*Hypoxis hygrometrica*	All specimens on Black Mountain are *Hypoxis hygrometrica* var. *villosisepala*, but this variety was not described until after 1969.
Juncaceae	*Juncus sarophorus*	Reported in Department of the Capital Territory (1980) but record not supported by voucher specimen. Other ACT specimens are higher altitude species; assume mis-identification.
Juncaceae	*Luzula* sp.	Name was used in Gray and McKee (1969) when the genus was under revision. Assume the taxon is one of the species now known from Black Mountain.
Orchidaceae	*Caladenia dilatata*	Now considered to be *Caladenia atrovespa.*
Orchidaceae	*Caladenia praecox*	Now considered to be *Caladenia ustulata*.

Family	Scientific Name	Reason for exclusion
Orchidaceae	*Calochilus gracillimus*	Now considered to be *Calochilus therophilus*.
Orchidaceae	*Calochilus saprophyticus*	Identification on Black Mountain is dubious (Clements 2017).
Orchidaceae	*Corysanthes grumula*	Specimens with these names are mis-identifications of *Corysanthes incurva* (Clements 2017).
Orchidaceae	*Microtis oblonga*	A higher altitude species in the ACT; not cited for Black Mountain by Jones et al. (2008); assume mis-identification.
Orchidaceae	*Thelymitra alpina*	Record is from Jones et al. (2008) and appears to be based on one 'naturally occurring' specimen from ANBG that is likely to be *Thelymitra nuda* (Clements 2017).
Orchidaeeae	*Linguella setulosa*	Manuscript name only; the record from Black Mountain is *Linguella nana* and will be transferred to *Diplodium nanum* (Clements 2017).
Poaceae	*Aristida vagans*	Gray and McKee (1969) voucher specimen not located; Department of the Capital Territory (1980) record not supported by voucher specimen; species does not occur in the ACT; assume mis-identification.
Poaceae	*Dichelachne rara*	All other ACT specimens are higher altitude; voucher specimen in Gray and McKee (1969) re-detted to *Dichelachne sieberiana*.
Poaceae	*Eragrostis leptostachya*	Specimen re-detted to *Eragrostis curvula*.
Poaceae	*Poa caespitosa auct*-group	Name was used in Gray and McKee (1969) when the taxon was under revision. Assume it is one of the species now known from Black Mountain.
Poaceae	*Poa meionectes*	Species not considered to occur in the ACT (Lepschi 2016); assume mis-identification.
Poaceae	*Rytidosperma indutum*	Specimen re-detted to *Rytidosperma fulvum*.
Primulaceae	*Lysimachia arvensis* (blue flowered form)	Australian Plant Census does not differentiate between orange- and blue-flowered forms.
Rosaceae	*Cotoneater* cf *conspicua*	Department of the Capital Territory (1980) record not supported by voucher specimen; two other *Cotoneaster* species recorded in same general area by RW Purdie in 2009; assume mis-identification.
Sapindaceae	*Dodonaea viscosa* subsp. *cuneata*	Herbarium specimens originally listed as subsp. *cuneata* in ANHSIR were hand-detted as intermediates closer to subsp. *spatulata*; all specimens now listed under the latter name.

Appendix 2

Excluded species: located outside Black Mountain study area

The following species were assumed to lie outside the study area, based on the notes provided on herbarium specimens (as shown in the right-hand column) from which their location can be deduced or inferred with a reasonably high degree of confidence.

Family	Scientific Name	Reason for exclusion
Asteraceae	*Arctotheca populifolia*	Only recorded from cultivated areas in CSIRO grounds.
Asteraceae	*Gamochaeta americana*	Only recorded from CSIRO grounds and as a weed of suburban lawn.
Asteraceae	*Helminthotheca echioides*	Only recorded near farm house at junction of Old Weetangera Rd with Dryandra Street.
Asteraceae	*Podolepis decipiens* (formerly *P. jaceoides*)	Recorded from open forest on west side of Black Mountain: most likely refers to known population in Aranda Bushland.
Brassicaceae	*Raphanus raphanistrum*	Only recorded in recently disturbed ground or earth fill on lower eastern slopes of Black Mountain.
Loranthaceae	*Amyema cambagei*	Species normally parasitic on *Casuarina cunninghamiana*, a riparian tree; no riparian habitat is present in study area.
Chenopodiaceae	*Atriplex prostrata*	Only recorded from shore of Lake Burley Griffin and Black Mountain Peninsula.
Fabaceae	*Cullen microcephalum*	Recorded location on Black Mountain was prior to construction of Caswell Drive. Species found in flower in Snow Gums section (W of Caswell Drive) of Aranda Bushland Nature Reserve in December 2014. No plants found at that time in similar habitat searched in Black Mountain Nature Reserve (on east side of Caswell Drive).
Fabaceae	*Pultenaea laxiflora*	Closest record is Belconnen Way near Haydon Drive.
Salicaceae	*Salix pendulina* nothovar. × *pendulina*	Sole record is a damp gully on SE base of Black Mountain; no plants seen in any gullies/creek lines in SE lower slopes during 2013-2017 field work.
Cyperaceae	*Schoenoplectus validus*	Sole record is E foot of Black Mountain in "heavy mud in water to 20 cm depth … in a small shallow permanent swamp". Other collections by botanist on same day from same general location indicate records were east of ANBG.
Orchidaceae	*Chiloglottis* × *pescottiana*	Only known from ANBG.
Orchidaceae	*Spiranthes alticola*	Only known from ANBG.
Poaceae	*Echinochloa esculenta*	Only recorded between caravan park and Dryandra Street, i.e. east of Frith Road.
Poaceae	*Rytidosperma richardsonii*	Only recorded from CSIRO grounds.