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Vegetation types and vegetation dynamics on Black Mountain

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Abstract. Black Mountain Nature Reserve and adjacent protected areas contain representative examples of dry sclerophyll forest and grassy woodland communities typical of those found on the southern tablelands. Although the vegetation found on the mountain today is recovering from the impacts of a variety of land use changes over a period of over 150 years, it is floristically and structurally diverse. Five vegetation types which have been described on Black Mountain are summarised in this paper, and the factors affecting their distribution, composition and structure are detailed. Although the primary environmental drivers of climate, geology and landform have organised plant distribution on Black Mountain over long periods of time, short-term changes in structure and composition are driven by local disturbances resulting from fire, drought, storms, windthrow, dieback, thinning and clearing.

1. Introduction

The area comprising Black Mountain has had a chequered history of land use over the more than 190 years since European squatters first colonised the Limestone Plains in 1824 (Watson 1938). Although grazing was primarily focussed on the grasslands and grassy woodlands found on flatter terrain, Black Mountain was used for rough grazing and some areas were cleared, particularly on the southern lower slopes, while other areas to the north were thinned of their eucalypt canopy for grazing or for firewood collection (Coyne 1969; Fraser 1981; Fitzgerald 1987). Importantly though, at no stage were the upper slopes of Black Mountain fully cleared of their vegetation cover and this is apparent in the earliest paintings and photographs of the mountain (Fitzgerald 1987; Gillespie 1991) (Fig. 1).

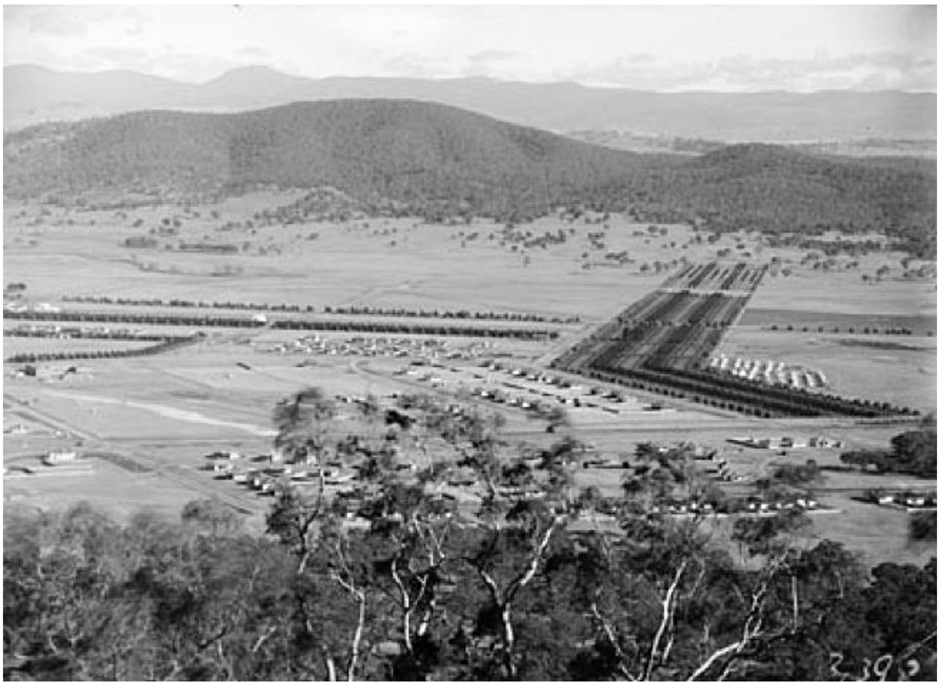

Fig. 1. View from Mount Ainslie to Black Mountain, showing Northbourne Avenue and Haig Park, 1927. Black Mountain and Little Black Mountain in middle distance; Mt. Coree and Brindabella Range in far distance. Photo: National Archives of Australia, A3348, 14.

Much of the vegetation structure observed today is recovering from the effects of past thinning and fire and although the vegetation now found on the mountain cannot be considered 'pristine', it is nonetheless still representative of the variation in composition and structure to be expected in hillslope country on the tablelands. In broad terms, the plant communities found on Black Mountain are primarily Southern Tableland Dry Sclerophyll Forest, with smaller patches of Southern Tableland Grassy Woodland and many of the species found on Black Mountain occur in similar environments north and south along the NSW tablelands (Keith 2004).

2. Primary environmental factors affecting vegetation distribution

There are many drivers of plant species composition and vegetation structure, but at a regional scale rainfall and temperature characteristics dictate maximum vegetation biomass potential, plant growth forms and plant species richness (Eyre 1971; Woodward 1987; Archibold 1995). At more local scales, lithology, aspect and slope determine microclimatic and soil conditions which in turn influence plant species composition (Kruckeberg 2002). The resulting patterns of species and vegetation structure are further mediated by a variety of disturbance regimes, particularly drought and fire, operating on the available pool of plant species (White 1979; Bond and van Wilgen 1996; Zeppel et al. 2015). What is true generally regarding vegetation patterns globally is also applicable to the distribution, abundance and dynamics of plant populations and vegetation types on Black Mountain.

Over the past 50 years a variety of studies has been undertaken on Black Mountain examining factors affecting plant occurrence there, as discussed in the following sections.

2.1 Rainfall and temperature

The nearest weather station to Black Mountain is the 'Australian National Botanic Gardens' station (ANBG), with rainfall records from 1968 to 2018. Based on these records, the area immediately adjacent to Black Mountain has a mean annual rainfall of 693 mm, with the lowest recorded annual rainfall being 328.5 mm in 1982 and the highest 1033.5 mm in 1974. Equivalent statistics for the 'Canberra Airport Comparison' station (CAC), with records from 1939 to 2010, show a mean annual rainfall of 615.4 mm, the lowest recorded annual rainfall 261.6 mm in 1982 and the highest 1062.5 mm in 1950. Long-term temperature records are not recorded for the ANBG station, however those for the CAC station show a mean annual maximum temperature of 19.7 ^{0}C and a mean annual minimum temperature of 6.5 ^{0}C, with the lowest recorded temperature 10.0 ^{0}C in July 1971 and the highest 42.2 ^{0}C in February 1968. In most years, there is a 40 ^{0}C range in temperature from winter to summer. In theory, Canberra has an even spread of rainfall throughout the year, but overall there is a trend for slightly higher rainfall in spring.

These statistics reflect the extremes in temperature and rainfall that are typical of tablelands climates and which put a strong environmental sieve on which plant species can cope and persist on Black Mountain.

2.2 Lithology and soils

Three major types of lithology are found on Black Mountain, deposited between 460 to 430 million years ago: a large area of Early Silurian Black Mountain Sandstone composed of quartz sandstone found around the summit area and eastern slopes; a small area of Early Silurian State Circle Shale composed of graptolitic shale found immediately north and south of, and bounding, the larger area of Black Mountain Sandstone; and the Late Ordovician Pittman Formation composed of shale, mudstone, sandstone, siltstone and radiolarian chert found on the western slopes (Opik 1958; Strusz and Henderson 1971; Abell et al. 2008; Finlayson 2008). Prominent sandstone outcrops occur on the steeper higher parts of Black Mountain near the summit, with fewer and less obvious outcrops present on the lower slopes and footslopes, including on Little Black Mountain.

Walker (1978) and Sleeman and Walker (1979) characterised soil landscapes for the Canberra area. Based on their classification, two associations occur on Black Mountain: the Umburra unit on ridges and steep side slopes, and the Russell unit found on fan slopes, which essentially map to the Black Mountain Sandstone and Pittman Formation lithology types respectively. The Umburra unit is characterised by shallow lithosols with little profile differentiation whereas the Russell unit consists of deeper podzolic soils: red podzolics on freely drained slopes and yellow podzolics in areas of more impeded drainage (Tongway 2018).

2.3 Aspect and slope

Pook and Moore (1966) studied the influence of aspect on species distribution and vegetation structure in dry sclerophyll forest on the eastern side of Black Mountain. They investigated the distribution and abundance of six eucalypt species (Apple Box, *Eucalyptus bridgesiana*; Broad-leaved Peppermint, *E. dives*; Red Stringybark, *E. macrorhyncha*; Brittle Gum, *E. mannifera*; Red Box, *E. polyanthemos*; Scribbly Gum, *E. rossii*) between northern and southern aspects and found that *E. rossii* and *E. macrorhyncha* stems were the most numerically abundant. Although both species occurred on either aspect, there was a significant difference in the abundance of these species in relation to aspect, with *E. rossii* dominating on drier northern aspects and *E. macrorhyncha* dominating on moister southern aspects. Subsequent laboratory work by Roden and Ball (1996) showed that the responses of the species to high temperature and water deficit were consistent with their distribution on Black Mountain. Although the other eucalypt species were numerically less common, *E. polyanthemos* showed a preference for northern aspects and *E. mannifera*, *E. bridgesiana* and *E. dives* a preference for southern aspects. This is consistent with patterns of eucalypt distribution in other areas of Black Mountain, where *E. rossii* and *E. polyanthemos* are dominant on the western flanks – the former on steep rocky upper slopes and the latter on slightly gentler mid to lower slopes.

Of the understorey species studied, *Phyllanthus hirtellus*, *Dillwynia phylicoides*, *Hakea decurrens, Goodenia hederacea* var. *hederacea* and *Pomax umbellata* had a strong preference for northern aspects; and *Poa sieberiana*, *Monotoca scoparia*, *Daviesia mimosoides* subsp. *mimosoides* and *Acacia buxifolia* had a strong preference for southern aspects.

3. Vegetation types

Although vegetation surveys have been published for other parts of Canberra Nature Park including Mt Majura and Mt Ainslie (Ingwersen et al. 1974), no equivalent published work exists for Black Mountain. In regional terms, the vegetation occurring on Black Mountain has been defined as *E. macrorhyncha – E. rossii* Dry Sclerophyll Forest by Pryor (1938) and was mapped as the same unit by National Capital Development Commission (1982).

A number of unpublished theses undertaken through ANU have researched a variety of aspects of plant distribution and vegetation dynamics on Black Mountain. Principal among these is the work of Coyne (1969) who used air photo interpretation and belt transects to describe and map vegetation types based on the number of tree stems 1.2 m above ground level. Species dominants for a particular vegetation type are based on the predominant species as measured by stem tally. Coyne mapped six units (Table 1) based on the percentage dominance of stems.

In relation to vegetation structure (Specht 1981; Specht 1983), tree heights and spacing are such that vegetation types 1, 2a, 2b, 3 and 4 have an Open Forest structure, whereas vegetation type 5 has a Woodland structure. Disturbance history has affected stem densities and stem diameters within these overall structural classes. In addition to these mapped vegetation types, there are also smaller areas on the south-west and south-east sides of Black Mountain containing derived Shrubland dominated by Burgan (*Kunzea ericoides*) and tea trees (*Leptospermum* spp.) and also areas of derived Grassland dominated by a rich mixture of forbs and native grasses (Pavlovic 1982). Vegetation types 1 to 3 occupy the most area on Black Mountain, with small areas of vegetation type 4. Given the steep terrain and sandstone soils found on Black Mountain, there are only limited occurrences of vegetation type 5 (Osler 1991), but it is more widespread in other parts of Canberra Nature Park including Ainslie–Majura and Goorooyarroo. As can be seen from

Table 1, there are considerable overlaps in the occurrence of eucalypt species across the first four vegetation types, with shifts in dominance occurring with changes in aspect and slope.

Table 1. Vegetation types from Coyne (1969)

Veg. Type	Dominant eucalypts	Notes
1	*Eucalyptus macrorhyncha* – *E. rossii* (with some *E. mannifera*, *E. dives* and *E. bridgesiana*)	Restricted to south facing slopes (15^0–30^0).
2a	*E. rossii* – *E. macrorhyncha* Large Stem Sizes (with some *E. polyanthemos*)	Restricted to northerly slopes (to 30^0), but extends over crests of E–W spurs onto upper parts of southerly slopes.
2b*	*E. rossii* – *E. macrorhyncha* Small Stem Sizes (with some *E. mannifera*, *E. dives* and *E. melliodora*)	Restricted to northerly slopes, but extends over crests of E–W spurs onto upper parts of southerly slopes; mostly associated with gently sloping and accessible areas but also occurs on steep slopes west of the summit.
3	*E. polyanthemos* (with some *E. macrorhyncha*, *E. rossii*, *E. mannifera* and *E. blakelyi*)	Occurs on NW to W facing slopes.
4	*E. dives*	Almost pure stand restricted to very steep (35^0) S-facing slope adjacent to Lake Burley Griffin with low solar radiation. An abrupt transition into *E. macrorhyncha* possibly because *E. dives* occurs on colluviums. *Eucalyptus dives* also occurs along the lower parts of the creek running SW from the summit, and scattered trees occur in the NW and SE of the reserve on creek lines associated with gentle topography.
5	*E. blakelyi* – *E. melliodora*	Occurs in broad depressions marking drainage lines <640 m altitude; Blakely's Red Gum (*E. blakelyi*) occurs only in depressions on alluvial soils of drainage lines; Yellow Box (*E. melliodora*) extends further away.

* Coyne included an area mapped as 2b on a southerly aspect that was predominantly *E. mannifera* with some *E. macrorhyncha*.

While there is a high diversity of vascular plants found on Black Mountain, with 393 native species being recorded up to late 2017 (Purdie 2018), only a small number of these species make up the bulk of the vegetation biomass, notwithstanding the biomass contributed by eucalypts. The most widespread and abundant understorey species providing substantial cover on Black Mountain are bitter pea (*Daviesia mimosoides* subsp. *mimosoides*)—a leguminous shrub growing up to 2 m in height—and Red-anther Wallaby Grass (*Rytidosperma pallidum*)—a tussock grass growing to 0.5 m in height and with flowering stems up to 2 m. The latter species occurs in all communities on both steep hillslopes and more gentle footslopes and provides considerable cover and potential wildlife habitat, but is less abundant in vegetation type 5. Areas with southern aspects also tend to have populations of the small tussock snow grass (*Poa sieberiana*). In some exposed northern aspects in the north-west slopes of Black Mountain, *R. pallidum* is replaced by Narrow Swordsedge (*Lepidosperma gunnii*).

Many of the other understorey species that occur on Black Mountain, despite being common, generally occur at lower abundances than the previously mentioned species. Medium sized shrubs that commonly occur in a variety of situations on Black Mountain include *Acacia genistifolia*, *Acacia buxifolia*, *Dillwynia phylicoides*, *Brachyloma daphnoides* and *Leptospermum multicaule*, with occasional patches of *Grevillea alpina*. Common undershrubs and herbs include *Hibbertia obtusifolia*, *Hibbertia calycina*, *Leucopogon virgatus*, *Gonocarpus tetragynus* and *Goodenia hederacea* var. *hederacea*.

4. Vegetation dynamics

The primary environmental factors outlined in section 4 above provide background selection pressure on plant species over long periods of evolutionary time. To understand just how dynamic vegetation can be, it is interesting to contemplate work done by Costin and Polach (1972) on slope deposits on the eastern side of Black Mountain, which are periglacial in origin and date from 27,800 (+2500–1900) years BP. Under the cold, dry climate indicated for that period, Black Mountain is likely to have been entirely treeless or else covered in scattered populations of snow gum (*Eucalyptus pauciflora*). A subsequent warming climate has seen a reduction in glacial and periglacial conditions and the evolution of forest and woodland ecosystems in south-eastern Australia. Although snow gum is not now present on Black Mountain per se, the frost hollow area south of the Aranda Bushland does contain a remnant population of this species. Snow gum is now restricted to cold air drainage areas on the tablelands as well as in higher altitude subalpine ecosystems.

A variety of disturbance factors also influence vegetation structure, plant species richness and community composition at local scales over the short- to medium-term. The major impacts on vegetation structure and composition in more recent times primarily occurred early in European settlement and the past 50 years has mainly seen vegetation in various stages of recovery after these past disturbances. The primary disturbance factors that have affected Black Mountain in historical times have been fire; drought; storms and windthrow; dieback; thinning and clearing.

The fire ecology of Black Mountain is covered in detail in Doherty (2018), so the following sections concentrate on the influences and effects of the other five factors.

4.1 Drought

In June 1965 Pook et al. (1966) studied the effects of a severe drought on tree species in the ACT, with some samples undertaken on Black Mountain. The drought had extended over the first half of 1965, and by June had reputedly resulted in the driest conditions for 200 years. They observed that *E. rossii* and *E. macrorhyncha* on northerly aspects showed signs of drought stress, whereas *E. melliodora* and *E. blakelyi* on lower slopes and flats did not exhibit such signs. The variation in species response largely reflected the soil type and aspect that they occurred on. Based on ring counts, many of the trees that were severely affected, including some apparent tree death, were more than 100 years old, ranging up to 200–300 years old. Many of the severely affected trees in the study had resprouted via epicormic growth by October 1965. It should be noted that as there was no follow up study over subsequent seasons (post February 1966), some of the trees that were assumed to be dead from drought effects at the time of the study may have eventually resprouted from epicormic shoots later, as there can be a delayed recovery response in drought affected eucalypts one or two seasons post disturbance (Doherty personal observation).

This study reinforces the fact that aspect and soil depth are critically important factors affecting plant distribution, amplifying the effects of rainfall and temperature and putting selective pressure on species adaptations to climate variability and particularly, climatic extremes. The effects of drought on understorey vegetation have not been formally studied on Black Mountain, but the ability of Red-anther Wallaby Grass (*Rytidosperma pallidum*) to persist on drier aspects compared with Snow Grass (*Poa sieberiana*) reflects similar differences in ability to cope with such extremes.

4.2 Storms and Windthrow

While occasional periods of drought can induce tree mortality; storms and windthrow can also result in localised but significant impacts including erosion, tree damage and tree death, changing canopy structure over the short- to medium-term i.e. a few decades. In March 2007 a severe thunderstorm caused large amounts of rain and hail to fall on the western side of Black Mountain. The resultant overland flow caused sheet erosion and displaced large amounts of leaf litter, exposing bare mineral soil (Fig. 2 and Fig. 3). Wind damage during storm events in 2016–2017 was evidenced by trunks and upper branches of eucalypts being snapped off and trees blown over completely in waterlogged soil (Fig. 4). This usually results in epicormic and basal spouting which can result in multistemmed trees, but can also lead to some tree death.

Fig. 2. Displacement of leaf litter from overland flow, lower western slopes. Photo: M Doherty.

Fig. 3. Deposition of eroded material downslope, lower western slopes. Note accumulation of material around obstacles such as branches and tussocks. Photo: M Doherty.

Fig. 4. Windthrow damage of mature trees, lower north-western slopes, March 2017. Photo: R Purdie.

The redistribution of material in such events can result in persistent bare patches, but also the movement and germination of seeds in areas of deposition. While this process can result in patterned vegetation bands, such patterns are not obvious in the understorey vegetation of Black Mountain.

4.3 Dieback

Climatic variability and climatic extremes also feed into the role that soil pathogens play in affecting vegetation structure and community composition through plant death. A significant amount of research was undertaken on Black Mountain into the distribution and effects on vegetation of the fungal pathogens *Phytophthora cinnamomi* and *Phytophthora drechsleri* during the 1970s. Pratt and Wrigley (1970) surveyed *P. cinnamomi* in the Australian National Botanic Gardens and found that in addition to planted native species, the pathogen was also found on *Eucalyptus macrorhyncha* and *Pultenaea procumbens* in the gardens and had also affected *Daviesia* spp. and *Dillwynia* spp. in the adjacent Black Mountain Reserve. Subsequent work on Black Mountain (Pratt 1973; Pratt and Heather 1973a, 1973b) revealed that of the eucalypt species found there, *E. rossii* and *E. macrorhyncha* were most susceptible to *Phytophthora* dieback and that the pathogen was present in the root zones of many understorey species. Effects of the pathogen were apparent on south facing slopes near the summit of Black Mountain, prior to the building of the current Black Mountain tower. Run off from road surfaces into areas that were inherently moist was thought to be a primary reason for its impact in this area which still exhibits dieback symptoms today. Taylor (1974) carried out detailed surveys on Black Mountain for both species of *Phytophthora* and found that they were widespread, particularly next to roads, tracks and disturbed areas with *P. drechsleri* also found in roadside plantings. Although both species are thought to have established independently, it is ultimately unclear whether they are introduced or native to the area.

The prime reason for the effects of *Phytophthora* being prominent in 1970–1971 was an unusually wet summer in 1969–1970. Subsequently, the effects of the pathogen have become less apparent, and by the 1990s, recovery had occurred in affected areas (Smith 1979; Weste 1994) and no major impacts have been reported recently (McDougall 2005). Such episodic outbreaks are to be expected and *Phytophthora* is still in the Black Mountain ecosystem, but its effects only become apparent during unusually wet summers. The synergistic effects of climate and microclimate mean that southerly aspects or moist communities are ultimately more susceptible to fungal dieback when conditions are conducive to *Phytophthora* outbreaks. This is yet another factor selecting for differential occurrence of eucalypts across the Black Mountain landscape.

4.4 Thinning and firewood collection

The extraction of firewood from the less steep lower western slopes of Black Mountain has resulted in many small and multi-stemmed individuals and few larger diameter trees. Subsequent cutting for firewood is thought to have occurred primarily across the western flanks of Black Mountain. This can be seen in Coyne (1969) where tabulating stems by size class shows differences in size class distributions on different parts of Black Mountain and in different vegetation types. Table 2 shows this for the four major vegetation types defined by Coyne.

Table 2. Vegetation types and eucalypt size classes from Coyne (1969)

Vegetation type	Size class (dbh) with number of stems and percentage			
	7.5–23 cm	**25–42 cm**	**43–59 cm**	**60+ cm**
1	436 (75.3%)	121 (20.9 %)	17 (2.9 %)	5 (0.9 %)
2a	223 (61.4 %)	97 (26.7 %)	29 (8.0 %)	14 (3.9 %)
2b	2083 (94.4 %)*	115 (5.2 %)	5 (0.2 %)	5 (0.2 %)
3	373 (98.4 %)*	6 (1.6 %)	-	-

* High proportion of small diameter stems thought to be a result coppicing after past wood cutting. Both of these vegetation types are in more accessible areas. Red Box was preferred for firewood and few mature Red Box trees remained on Black Mountain in 1969

Two patterns stand out. In relation to the occurrence of *E. rossii* in vegetation types 2a and 2b, the larger stems and hence older individuals found in 2a occur on much steeper slopes than the smaller stem sizes found in type 2b on lower slopes where firewood collection was undertaken (Fig. 5 and Fig. 6). In relation to *E. polyanthemos*, the preponderance of smaller stem sizes reflects the fact that this species is prized for firewood and was also heavily cut over in the past on the western slopes (Fig. 7).

Given the eucalypt density in many of these areas, little seedling recruitment is apparent from year to year. However, this is to be expected in fully stocked stands and even bare areas are not necessarily colonised quickly by eucalypts. During 1949–1950 Jacobs (1950) investigated growth plots that were established in 1928–1930 for firewood coppice and mentions incidentally the fact that bare areas from 1928 were extremely slow to be colonised by eucalypts in the absence of fire, even after nearly 20 years.

4.5 Clearing

As stated previously, much of Black Mountain has been affected to greater or lesser degrees by thinning, but only small areas in the current reserve were cleared outright. These were in areas on the eastern and particularly the southern side of Black Mountain. Areas in the east are incorporated into what is now CSIRO and Australian National Botanic Gardens sites. Areas on the south side which are regenerating after having been cleared can be seen just above Parkes Way and are apparent as cleared areas in early photographs. Pavlovic (1982) studied regenerating areas in Smith’s Paddock on the south-west side of Black Mountain which are now adjacent to Caswell Drive, comparing weed seed banks in grassland and adjacent shrubland. The area was previously cleared and had been grazed until 1969.

Fig. 5. Long unburnt old growth *Eucalyptus rossii* on northern slopes of Black Mountain, July 2016: unburnt uncut at left; post disturbance coppice at right. Coyne (1969) Vegetation Type 2a. Photos: M Doherty.

Fig. 6. Small stems of *Eucalyptus rossii* on lower western flanks of Black Mountain, June 2003. Coyne (1969) Vegetation Type 2b. Photo: M Doherty.

Fig. 7. Small stems of *Eucalyptus polyanthemos* on lower western flanks of Black Mountain, June 2003. Coyne (1969) Vegetation Type 3. Photo: M Doherty.

Although both grassland and shrubland are currently dominated by native species above ground, both types have considerable weedy soil seed banks dominated by introduced annuals. The weed flora currently present is a legacy from past grazing and although a significant component of the overall current species diversity, contributes less to overall biomass than the current cover of native species. In this particular instance, the grassland is gradually being encroached by shrubs such as Burgan (*Kunzea ericoides*) which in the long run may form a stable 'derived' shrubland community, as has occurred in and around Tidbinbilla Nature Reserve (Kirschbaum and Williams 1991). Interestingly, Burgan was not included in Pavolvic's species list, indicating it was extremely rare or totally absent from the study area at the time. It has only taken 35 years for the Burgan in this area to go from very low abundance to its current density.

5. Management implications over the next 50 years

In the absence of further major broad-scale disturbance on Black Mountain, the structure and composition of vegetation across the five vegetation types may exhibit little obvious change over the next 50 years. It is expected that areas which were thinned or coppiced in the past will continue to self-thin and that the age structure will move gradually to larger size classes. Smaller areas which are currently old growth – notably very large specimens of *E. rossii* – will likely look much the same. Such little work has been undertaken on the aging of eucalypts in dry sclerophyll communities that the upper end of their longevity is not known, but it is at least many hundreds of years (Banks 1997). The ability of most eucalypts to resprout or coppice after a main trunk fails also enables a degree of 'rejuvenation' of individuals and at least some of the stems we now see as being relatively young are regenerated stems from a much older organism. Hence the actual age of a tree can be much older than that of the current stem. The main factor that will primarily affect vegetation on Black Mountain over the next 50 years is fire management and the interplay of fire frequency, fire intensity and fire seasonality as they are modified by background shifts in rainfall and temperature patterns. This is discussed in detail in Doherty (2018).

6. References

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