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Scientific collecting, monitoring and research on Black Mountain

Rosemary W Purdie

rwpurdie@netspeed.com.au

Abstract. Black Mountain has been the location of scientific endeavour since the 1920s, the earliest work related to collecting specimens of its biota. Over the last nine decades more than 4000 plant specimens from the area have been collected by around 212 botanists, most associated with the Australian National Herbarium, and tens of thousands of insect specimens by at least 184 entomologists, most associated with the Australian National Insect Collection. These collections have resulted in the area being the type locality for at least 197 species (2 lichens, 10 flowering plants, and the rest invertebrates). The first research reports relating to the area were published in the 1950s. Since then over 130 papers, theses or other reports have been written, more than half published since 1990. Just over half the papers relate to faunal studies, 31% to flora and vegetation, 11% to the physical environment and the rest to fire ecology. Around 80% of papers were by scientists from ANU, the University of Canberra and Commonwealth research institutions. ACT Government scientists commenced research and monitoring in the area in the mid-1970s, their work mostly relating to vegetation, vertebrate fauna and monitoring the impacts of management burns. Citizen science documenting the area's biodiversity has been prominent since the 1960s and includes the activities of community groups and many individuals. The collective efforts of professional and citizen scientists have resulted in Black Mountain's biota probably being more comprehensively studied and documented that any other area of comparable size in the ACT. This reflects a combination of key collecting and research institutions being located on Black Mountain's footslopes and its accessibility to local citizens. The area remains a fertile place for research to underpin its future management.

1. Introduction

The first management plan for the newly declared Black Mountain Reserve recognised that scientists had been using the area as a research site for some time, noting "Many scientists at CSIRO have traditionally just hopped over the back fence to collect, not only insects but plant specimens and other animals" (Elliott and Douglas 1974). They concluded that research in the reserve should be encouraged, although "it must at all times be subject to the approval and control of a responsible, nominated authority" and "should generally be limited to those [programs] which cannot be done elsewhere, are unlikely to change the general character of the area and do not conflict with other approved public uses".

In the decades after, reports on the ecological resources of the Australian Capital Territory noted the increasing scientific knowledge about and scientific value of Black Mountain Reserve. The values included the extensive stands of *Eucalyptus macrorhyncha – E. rossii* vegetation, the presence of a small Grey Kangaroo population, and the occurrence of 21 uncommon plant species "particularly orchids of which over two-thirds of the ACT species are found here" (Shorthouse 1979). By 1984, the *E. macrorhyncha – E. rossii* vegetation community was considered to "represent a valuable record of the normal variation in the community dominants" and, with adjacent areas, provide important wildlife habitat (National Capital Development Commission 1984). Two additional uncommon plant species were reported to be present and the occurrence of two-thirds of the ACT orchid species reiterated. By 1990 more plant species from the reserve were considered to be uncommon and the area was referred to as one of four sites in the ACT that had been studied "relatively intensively", largely because of insect collecting by CSIRO staff from a trap located adjacent to what is now the Australian National Botanic Gardens (ANBG) (Hogg 1990). Hogg commented that Black Mountain was "the most extensively collected area in the ACT" and "particularly important as a type locality and as a source of baseline data" for insects. He also mentioned that the Grass Triggerplant (*Stylidium graminifolium*) collected at various locations on Black Mountain was one of several native herb species being investigated for use in natural landscaping.

The Black Mountain area has continued to be the location of considerable scientific collecting and other research activities since 1970. The following sections of this paper provide an overview of the work carried out there (excluding ANBG) by both professional and citizen scientists, some of the work starting nine decades ago. The paper focusses on activities that have not been published and should be read in conjunction with the Black Mountain Symposium background papers relating to plant collections and collectors (Purdie 2018a) and published research (Purdie 2018b).

2. Biodiversity research: scientific collections and collectors

Scientists have been actively collecting plants and animals from Black Mountain since the late 1920s. A detailed analysis of the plant collections and collectors from the area is provided in Purdie (2018a). In summary, over 4000 vascular and non-vascular Black Mountain plant specimens have been lodged in the Australian National Herbarium and represent the activity of at least 212 people. Around 83% of the collections have been made by ANBG and CSIRO staff and associates, most working at the herbarium. The main collectors include William Hartley, Ted Moore and Erwin Gauba in the period 1927–1954**;** Irene Beeton, Max Gray, Hugh McKee, Pam McDonnell and Roy Pullen from 1955 to 1969; Laurie Adams, Jack Elix, Betty Hain, James Hoare, Roy Pullen, Heinar Streimann, Joan Taylor and Doug Verdon from 1970 to 1989; and Mark Clements, Judith Curnow, David Jones, Heino Lepp and Rosemary Purdie from 1990 onwards. Their activity over these decades reflected a combination of personal collecting interests and changing institutional priorities (Purdie 2018a).

Records in the Australian National Herbarium Specimen Information Register (ANHSIR, http://www.anbg.gov.au/cgi-bin/anhsir) indicate that from 1961 to the present at least 56 seed collections have also been made of plants from Black Mountain, the majority by ANBG staff. Early collections (1961–1994) were often for research purposes or cultivating the species in the gardens. While research is still a common use of recent collections, those made since 2005 have mostly been to help build conservation stocks of the local flora in the ANBG's National Seed Bank (http://www.anbg.gov.au/gardens/living/seedbank/) (Guja 2018). Around two-thirds of these recent collections were made by ANBG Seed Bank Manager Sarah Fethers, and include seed from common shrub, subshrub, grass and forb species.

Faunal specimens from Black Mountain include a small number of vertebrates housed in CSIRO's Australian National Wildlife Collection (https://www.csiro.au/en/Research/Collections/ANWC); they are species of birds, mammals and reptiles (Table 1; Purdie unpublished–a). Around 56% of the specimens were collected in the 1960s.

Table 1. Faunal specimens from Black Mountain held in the Australian National Wildlife Collection

Type	No. of species	No. of specimens	Years when collected
Birds	7	9	1961, 1965, 1971, 1983, 1988, 2003
Mammals	8	21	1961, 1966–67, 1985
Reptiles	6	13	1968–1971
Total	**21**	**43**	

Entomologists from CSIRO have been collecting invertebrates from Black Mountain since the site was selected as the location of the (then) CSIR[1] Division of Economic Entomology in 1928. The collecting activity increased in the early 1950s when Ian Common started operating a fixed light trap on a daily basis in nearby bushland on the eastern footslopes of the mountain, adjacent to what is now the ANBG (Upton 1997, 2018). The initial trap (Fig. 1a) was replaced around 1963 by a permanent, much larger weatherproof trap whose light was controlled automatically by a time switch (Upton 1997, 2018). The more sophisticated design of the trap (Common and Upton 1964) allowed fragile specimens, larger, heavy-bodied insects (such as beetles) and non-flying insects to be captured, including the first known specimens of a brachypterous Oecophorid moth. The trap was attended 365 days each year (Upton

[1] Council for Scientific and Industrial Research

1997) until the 1970s when it began to be used more intermittently (Edwards 2018). It remained in operation until at least the mid-1980s with species not previously recorded from Canberra still being captured then (Upton 1997). Flight intercept (Fig. 1b) and malaise traps (Purdie unpublished–b) were also used to capture insects from the area.

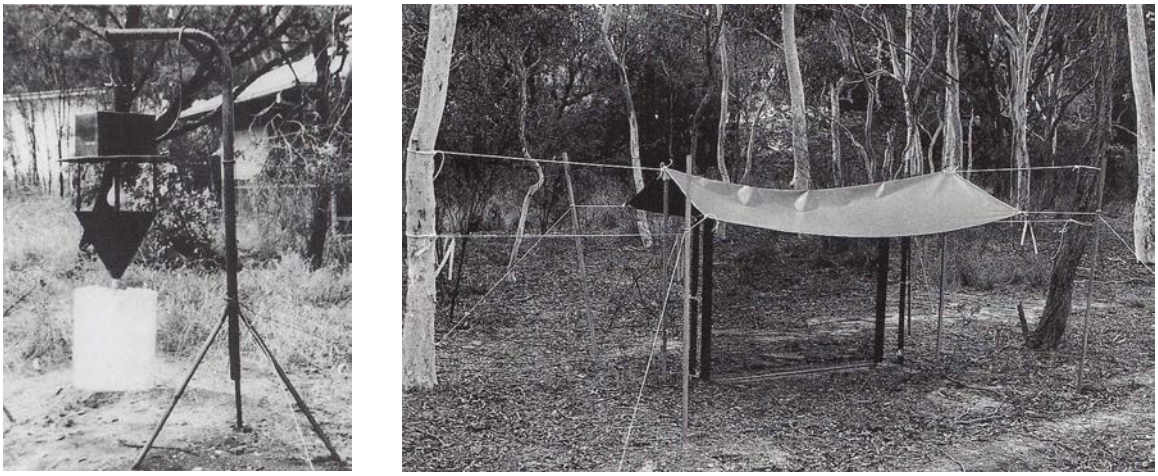

Fig. 1. CSIRO Division of Entomology insect collecting equipment on Black Mountain. a) left, Ian Common's fixed light trap, 1959. b) right, a flight intercept trap. Photos: from Upton (1997), pages 258 and 259.

Unlike the fully databased plants collections of the Australian National Herbarium (see Purdie 2018a), only a small proportion of the insect collection in CSIRO's Australian National Insect Collection (ANIC) has been databased. It is thus difficult to determine accurately the number of people who have collected insects from Black Mountain and the total number of specimens collected there, although the latter is likely to be in the order of tens of thousands (Pullen 2018a). The 4300 databased insect specimens from Black Mountain reflect the activity of c.150 people, of which around 70% were from ANIC and the remainder from a variety of Australian museums as well as various overseas bodies (Purdie unpublished–b). When other known collectors are included (Edwards 2018; Upton 2018), at least 184 people have made collections from Black Mountain (see Appendix 1)[2]. ANIC staff believed to have made use of Black Mountain for collecting and/or research are shown in Table 2; a considerable number of these people would not have made research collections but collected the odd or interesting specimen there from time to time (Upton 2018). Black Mountain's insect and other invertebrate fauna are discussed by Pullen (2018b).

Table 2. Collectors from ANIC over the decades from 1920 (Upton 2018). Shaded boxes indicate their periods of active collecting generally (i.e. not just on Black Mountain).

Name	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s
Holdaway, FG									
Kent Hughes, WP									
Evans, JW									
Fuller, ME									
Graham, LF									
Tillyard, RJ									
Hill, GF									
Mackerras, IMC									

[2] An analysis of the currently undatabased specimens from the area would be necessary to determine accurately the total number of collectors.

Name	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s
Tonnoir, AL									
Campbell, TG									
Mackerras, MJ									
Greaves, T									
Nicholson, AJ									
Gay, FJ									
Key, KHL									
Norris, KR									
Calaby, JH									
Paramonov, SJ									
Chinnick, LJ									
Riek, EF									
Carne, PB									
Colless, DH									
Common, IFB									
Wallace, MMH									
Taylor, KL									
Upton, MS									
Britton, EB									
Carver, M									
Taylor, RW									
Watson, JAL									
Cardale, J									
Zimmerman, EC									
Edwards, ED									
Lawrence, JF									
Naumann, ID									
Rentz, DCF									
Weir, TA									
Calder, AA									
Cranston, P									
Gullan, P									
Halliday, RB									
Horak, M									
Nielsen, ES									
Shattuck, SO									

3. Type specimens of biota collected from Black Mountain

At least 195 biological specimens collected from Black Mountain have been designated as holotypes[3], and an additional two specimens as lectotypes[4]. Black Mountain is thus the type locality for at least 197 species (see Appendix 2), 93% of them invertebrates and the remainder plants (Table 3). The plants comprise two lichens and 10 species of flowering plants, including nine orchids. The invertebrates

[3] A holotype is the single specimen used to formally describe a taxon new to science.
[4] A lectotype is a specimen designated as the type of a taxon when no holotype was designated by the person who originally described it.

include one spider, *Maratus calcitrans*, a peacock spider described in 2012, and 184 insect species. The latter include 75 species of flies, 31 ants, 29 beetles, 19 thrips, lower numbers of cockroaches, bugs and moths, one web spinner and one lacewing. One plant and two insect species are named after Black Mountain, viz. Black Mountain Leopard Orchid (*Diuris nigromontana*), the beetle *Leptostibina blackmontis* and the fly *Pseudoleucopis nigromontana.*

Table 3. Number of type species described from Black Mountain

Common Name (Order)	**Number of families**	**Number of species**	
		Holotype	**Lectotype**
Lichens			
Lichens	2	2	-
Flowering plants			
Orchids	1	9	-
Other	1	1	-
Total flowering plants	2	10	-
Spiders (Class Arachnida)			
Spiders	1	1	-
Insects (Class Insecta)			
Cockroaches (Blattodea)	4	3	2
Beetles (Coleoptera)	12	29	-
Flies (Diptera)	27	75	-
Web Spinners (Embioptera)	1	1	-
Bugs (Hemiptera)	4	13	-
Ants (Hymenoptera)	14	31	-
Moths (Lepidoptera)	5	10	-
Lacewings (Neuroptera)	1	1	-
Thrips (Thysanoptera)	2	19	-
Total insects	70	182	2
Total all organisms	**77**	**195**	**2**

Three of the insect species described from Black Mountain are linked with Scribbly Gum (*Eucalyptus rossii*), one of the most well-known trees in the area instantly recognisable by the prominent 'scribbles' on its bark (Fig. 2a). Entomologist Winifred Kent Hughes examined the scribbles on trees located on Black Mountain in 1931, and although at the time it was believed they were caused from damage to the bark by a beetle, Hughes was unable to locate any insects. André Tonnoir from ANIC made further investigations in 1933 and after discovering that a lepidopterous larva was responsible, sent two adult moths to expert AJ Turner who noted they were "an obscure and unknown species" (Upton 1997). When Turner was sent additional specimens in 1934 he indicated he was no closer to identifying the species and suggested specimens be sent to E Meyrick in England. The following year after moths emerged from pupae collected in February 1935 at Picadilly Circus by ANIC entomologist Tom Greaves (Cooke and Edwards 2007), the specimens were sent to Meyrick. He advised that they were of a species new to science that he had named *Ogmograptis scribula* (Upton 1997).

For the next seven decades *Ogmograptis scribula* was the only scribbly gum moth species described, although it was thought likely that other species would occur (Nielsen and Common 1991). In 1999 Canberra high school student Julia Cooke investigated the cause of the scribbles with the assistance of retired ANIC entomologist Ted Edwards. Detailed measurements of scribbles from three eucalypt

species in the ACT, including those on *E. rossii* trees growing on Black Mountain, suggested each eucalypt species may host a different species of *Ogmograptis* (Cooke and Edwards 2007). This prompted further research by a group of retired ANIC entomologists, including 96-year-old Max Day (McKay 2012). Their detailed field and laboratory studies, including DNA analysis, resulted in 11 new species of *Ogmograptis* being described in 2012 (Horak et al. 2012). They included three species (*O. barloworum, O. maxdayi and O. paucidentatus*) for which Black Mountain is the type locality and a fourth species (*O. racemosa*) whose type locality is the ANBG which also occurs on *E. rossii* trees on Black Mountain. Horak et al.'s work also revealed that 'ghost scribbles' present on *E. rossii* trees (Fig. 2b) are caused by larvae of possibly two species of a closely related genus *Tritymbia*.

Fig. 2. Scribbles on the bark of the Scribby Gum (*Eucalyptus rossii*). a) left, scribbles formed by species of *Ogmograptis* in two successive years, the most recent on the yellowish bark. b) right, a ghost scribble formed by a species of *Tritymbia.* Photos: R Purdie.

4. Geological, soil and ecological research and monitoring

4.1 Breadth of research and main institutions involved

A substantial body of ecological and physical research has been carried out on Black Mountain and is described in Purdie (2018b). In summary, the research is detailed in at least 94 papers published in scientific journals, 26 tertiary level theses and 14 other reports.

Over half the papers relate to faunal research, and include birds, invertebrates and mammals. Studies on the biology, behaviour and ecology of bird species on Black Mountain is a prominent feature of the faunal research, accounting for 75% of the references (see Purdie 2018b). They include 18 papers on the White-winged Chough by Rob Heinsohn and colleagues at the Australian National University, as well as seven papers on the Southern Boobook and six papers on raptors (including the Little Eagle and Wedge-tailed Eagle) by Jerry Olsen and colleagues from the University of Canberra.

Thirty-one per cent of the papers relate to vascular plants, non-vascular plant species (including the dieback fungus *Phytophthora*) and vegetation. They include studies on the diversity, phenology and pollinators of orchids, other plant–insect interactions, the breeding systems of several shrub species, growth rates of eucalypts, rare plants, the naturalisation of species used in landscaping and the floristic composition of the vegetation (see Purdie 2018b). Around 11% of the papers describe Black Mountain's geology, landforms and soil properties while the remainder relate to various aspects of fire ecology (see also Doherty 2018).

Researchers and post-graduate students from the Australian National University and the University of Canberra (and its predecessor the Canberra College of Advanced Education) account for 60% of the papers. Around 21% have been produced by scientists in CSIRO and other Commonwealth Government institutions in Canberra (Bureau of Mineral Resources, Forest Research Institute and Forestry and Timber Bureau), and include collaborative research with visiting overseas colleagues. Nine per cent of the papers were published in the 1950s–1960s, 28% in the 1970s–1980s, 47% in the 1990s–2000s and the remainder in the 2010s.

4.2 Activities of ACT Government scientists

Research by scientists in the ACT Government (and its predecessor Commonwealth Government departments) is largely focussed on management of the territory's biodiversity and conservation reserve estate and includes formal and informal monitoring of species and ecosystems. Because much of the work and data generated is unpublished, it is described in more detail here than published research relating to Black Mountain (see section 4.1 and Purdie 2018b) to provide a public record of it.

Ecological research on Black Mountain by scientists employed by the management agencies commenced around the early- to mid-1970s, with considerably more floristic than faunal studies being carried out in the following decades. Over 1975–1976 Kruno Kukolic completed the first comprehensive survey of Black Mountain's vertebrate fauna, together with that of the Ainslie–Majura area (Kukolic 1990). Little subsequent faunal research appears to have been carried out until the Conservation Research section of the ACT Government re-surveyed small ground-dwelling mammals on Black Mountain in 2009 using the same locations as Kukolic's (see Evans 2018a).

In March 1969 Frank Ingwersen commenced work as a botanist with the Commonwealth Department of Interior, having been appointed to carry out floristic research in the ACT's developing conservation reserve network. Most of Ingwersen's research on Black Mountain was done in the mid-1970s with Technical Assistant Jan Ward and focussed predominantly on the reserve's vegetation and associated faunal habitat types. Ingwersen and Ward established 59 plots each 20 m × 20 m to sample Black Mountain's vegetation along various topographic gradients and across the range of soil types present. In each plot they recorded data that included all plant species present, growth form (tree, shrub, subshrub etc), the life form of each species (i.e. the way in which it grows and its reproductive mechanisms for survival), cover class of the dominant species, overall cover of the tree, shrub and herb layers, and the diameter-at-breast-height (dbh) of the dominant trees (Ingwersen 2018). The intent was to publish a map and description of the vegetation (based on pattern analysis of the data) similar to that for the Mt Ainslie – Mt Majura reserves (Ingwersen et al. 1974). Although some of the data were analysed, the work was never published due to competing priorities. As part of her work from 1974 to 1983, Ward compiled a detailed flowering calendar of Black Mountain's plants based on fortnightly observations over several years, when she recorded the presence of buds, flowers and fruits on plants and each species' peak flowering period (Ingwersen 2018).

In the early 1990s ecologist Sarah Sharp began researching grassland vegetation in the ACT. On Black Mountain, she studied secondary grassland sites in Smith's Paddock from 1993 to 2001 (Sharp 2018). The work involved recording the diversity and cover/abundance of plant species each year in late spring to measure changes in species composition and vegetation structure. Sharp used five transects at fixed locations selected in part to determine whether or not Burgan (*Kunzea ericoides*) was spreading into the grassland (see Fig. 3). Sharp was assisted in some years by consultant ecologists Isobel Crawford and Alison Rowell.

Fig. 3. Secondary grassland studied by Sarah Sharp in Smith's Paddock on the lower south-west slopes of Black Mountain. The white × shows the Burgan (*Kunzea ericoides*) shrub zone in December 2016. Photo: R Purdie.

In 2010 and now working as a private consultant, Sharp undertook a landscape functional analysis survey of Canberra Nature Park (CNP) for the ACT Commissioner for Sustainability and Environment as part of the latter's formal investigation into the condition of the land in CNP and other areas. The purpose of Sharp's study was to assess the condition of the vegetation and habitat and determine the effects of grazing, vertebrate pests and weeds (Sharp 2011). In January that year she surveyed four transects in Black Mountain Nature Reserve, two in mature forest vegetation with coarse woody litter, one in grassy forest vegetation that had been burnt in 2009 and the last in the south-west secondary grassland. All but the recently burnt vegetation were considered to be in satisfactory condition, having a high level of stability, infiltration and nutrient cycling. Overall condition of Black Mountain Nature Reserve was assessed as being satisfactory (95–99% of the reserve), although the recently burnt areas (1–5% of the reserve) were assessed as approaching critical condition. Sharp noted that many parts of the reserve had been subject to frequent fires and that if burnt too frequently to maintain soil litter and soil biota, landscape function could be reduced. She recommended that landscape function be monitored at key locations on Black Mountain to ensure that "fires do not occur at a frequency that compromises stability, infiltration and nutrient cycling" (Sharp 2011). Other management issues Sharp observed included kangaroo grazing in the south-west secondary grassland, the erosion of several walking tracks and the use of some walking tracks by cyclists.

Research related specifically to the ACT Government's management burns (usually called hazard reduction or fuel reduction burns) on Black Mountain started in the 1990s when Frank Ingwersen initiated a project for University of Canberra student Sally Horsnell to develop a rapid assessment tool for monitoring the effect of the fires in the Black Mountain area (Ingwersen 2018). The work involved recording vegetation structure, supplemented by site profile sketches and photographs, and basic floristic data as relevant. The objective was to apply the tool before and after each burn in each fire management block Ingwersen had delineated across Black Mountain and the adjacent Bruce Ridge and Aranda Bushland areas, each 'block' being defined by sections of the road network and/or walking tracks. Blocks where the tool was initially trialled on Black Mountain included Smith's Paddock.

After the catastrophic 2003 wildfires in the ACT and the inclusion of Black Mountain in Canberra's Bushfire Abatement Zone, the priorities and schedules for fuel management in Black Mountain Nature Reserve and other parts of Canberra Nature Park were required to be detailed in annual bushfire operational plans (BOPs) (Emergency Services Authority 2004). Although each BOP initially focussed on just fuel management, from 2009 onwards they also took account of ecological factors via minimum and maximum inter-fire interval range targets specified in a new regional fire management plan (Anon

undated). In the early 2010s ecologist Hannah Matthews started monitoring the impact of BOP fuel reduction burns on dry sclerophyll vegetation in Canberra Nature Park. In 2011/12 she established 12 transects each 50 m long in the north-east of Black Mountain reserve, recording the vegetation type and plant species present along each transect prior to scheduled burns, and subsequently monitored them to record post-fire regeneration. As not all areas with her transects were burnt as part of the annual fuel reduction program less information than anticipated was collected (Seddon 2018), although some data contributed to the development of ecological guidelines to be used during BOP implementation (Kitchin and Matthews 2012).

In December 2013 ecologist Julian Seddon established a series of monitoring sites to examine the impacts of fire regimes on the structure and floristic richness of dry sclerophyll forest in the Black Mountain Sandstone area[5]. In Black Mountain Nature Reserve he set up 80 sites in locations designed to sample a range of fire frequency histories, time since fire, slope and aspect, using 50 m long transects at each site (Seddon 2018). In 2014 he used a subset of these (23 in total) to establish paired sites, around half of them burnt since 1980 and the remainder long unburnt. In these paired sites he used 50 m long transects to measure vegetation cover and growth form of plants, 50 m × 1 m transects to record woody species (trees and shrubs) and their height class, 20 m × 20 m plots to measure native species richness, and 50 m × 20 m plots to assess faunal habitat features including coarse woody debris and tree hollows. At sites located in areas scheduled for fuel reduction burns, all the data were measured pre-burn and in the first year post-burn, with the woody species' post-fire recovery mechanism (seed germination and/or vegetative regrowth) also recorded in the first year after being burnt. Only vegetation cover, growth form, and woody species/height were recorded subsequently. The plots have been monitored annually since being established, and the results used to inform fuel reduction burn programs in the area (Seddon 2018). A selection of the sites was also used as the basis for a citizen science project aimed at better understanding the impact of fire regimes on Black Mountain's orchid species (see section 5.8).

Ecologists in the ACT Government maintain a geographic information system (arcGIS) that holds data on the locations of significant vegetation types and habitats, and plant and animal species that may warrant protection or special consideration during fuel reduction burns. For Black Mountain, arcGIS data includes the locations of rare orchid species, rare or uncommon fire sensitive plants such as *Grevillea ramosissima*, *Callitris* spp., *Pomaderris* spp. and *Calytrix tetragona*, and moist habitats containing uncommon species restricted to such areas (e.g. ferns, sedges such as *Eleocharis atricha*). These data come from a variety of sources that include monitoring and informal observations by both ACT government staff and members of the community, including rare orchid records compiled by Jean Egan and Tony Wood (see section 5.8). These data are used to advise Fire Management Unit staff who implement the BOP fuel reduction burn program on the ground. Non-sensitive location data are publicly available through the website ACTmapi (www.actmapi.act.gov.au) in the 'Biodiversity/Rare and other important plants' layer of the 'Significant species, vegetation communities and registered trees' section.

Other research carried out on Black Mountain by ACT Government staff includes that of botanist Greg Baines who sampled individual Blakely's Red Gum (*Eucalyptus blakelyi*) trees there in 2017 as part of a wider study in the northern ACT examining the relationship between time since fire and the severity of tree dieback in the species (Baines 2018). Baines has also been mapping the vegetation of the ACT, and in 2018 used aerial photo interpretation to classify Black Mountain's vegetation using attributes including the three most dominant species in the tree, shrub and ground layers (Baines 2018). The mapping also calculated mean per cent canopy cover, maximum and mean tree height, and per cent shrub cover in each polygon using Lidar (light imaging ranging and detection). His maps of the vegetation communities are publicly available on ACTMapi in the 'Significant Species, Vegetation Communities and Registered Trees' section.

Many informal observations and research data related to the ACT's animals, plants and vegetation, including for Black Mountain, are also stored in databases maintained by the ACT Government. The ACT Wildlife Atlas contains records of wildlife sightings by staff (mainly rangers) that date back to the

[5] See Mulvaney (2018a) for a description of the Black Mountain Sandstone area.

1950s as well as data from faunal surveys by consultants (Evans 2018b). The ACT Vegetation Database includes floristic data from vegetation or other surveys/research by government staff, consultants and some community members (Mulvaney 2018b). Although the ACT Wildlife Atlas and Vegetation Database are for internal use by ACT Government staff, relevant data is shared with Canberra Nature Map (see section 5.6) and the Atlas of Living Australia (https://www.ala.org.au) whose databases are publicly accessible. Information from plant specimens held in the ACT Government's herbarium also became more widely accessible when the collection was incorporated into the Australian National Herbarium in 2005 (Lepschi 2018) and the data entered in the Australian National Herbarium Specimen Information Register (ANHSIR) database.

5. Citizen Science activities

Many individuals in the local community have helped to document Black Mountain's biodiversity and ecology, often as part of organised interest groups established relatively recently. As their work is generally not well known in the wider community, key groups, activities and individuals who have contributed their time and effort are outlined below.

5.1 Canberra Ornithologists Group

Since its establishment in 1964, the Canberra Ornithologists Group (COG) has encouraged its members to observe and record birds in the Canberra region to increase knowledge about the local avifauna and promote conservation of the species and their habitats. The initial opportunistic observations were replaced by systematic surveys in 1982, but all records have been maintained in the COG Database and used for producing annual reports about Canberra's avifauna (Fennell 2018). Black Mountain has been among the many locations where birds have been systematically recorded since early 1982, with more than 20 people regularly observing birds in the area and providing their records to COG. Key observers over the last few decades include Linda Beveridge, Con Boekel, Geoffrey Dabb, Chris Davey, Malcolm Fyfe, Michael Lenz, Ian McMahon and Nicki Taws. COG used its records to assess the significance of Black Mountain for bird habitat compared with Mt Ainslie and Mt Majura (Canberra Ornithologists Group 1986). The data were also used to compile a comprehensive list of Black Mountain reserve's current avifauna and assess changes in it from 1964 to 2016, as described in Fennell (2018).

5.2 Australian Native Plant Society Wednesday Walkers

Around 1992, some members of the Australian Native Plant Society, Canberra Region started doing walks on Wednesday afternoons in local bushland areas with interesting plants and recording species they observed (Clarke 2013). This evolved into the Wednesday Walkers group, who visit areas each week on Wednesday mornings to allow members to learn more about native plants in their natural environment and practice their plant identification skills. Gwyn and Geoff Clark guided many of the earlier walks. Ros Cornish organised them from 1996 until early 2016, after which Roger Farrow and Christine Kendrick took over until January 2017 when they handed organisation to Jo Walker, Julie Linder and Lesley Page (Geue 2018). From 2008 to early 2016, Cornish made lists of plants seen on the walks, initially recording species seen each week but later recording them for each location. Brigitta Wimmer and Helen Brewer subsequently took over this work. Cornish and Martin Butterfield put the walk lists and photographs of the plants on the ANPS website[6] and on the Atlas of Living Australia (Geue 2018).

Over the years Black Mountain has been a regular inclusion in the Wednesday Walks program, with periodic repeat visits to routes such as the Black Mountain Circuit (along the Forest Trail/Track), Black Mountain from the Botanic Gardens, and walks from entry points off Frith Road, Belconnen Way and Caswell Drive. The list of plants published on the ANPS website for each walk, and sometimes included as short articles in issues of the ANPC journal, provide a record of species in flower at various times of the year over different parts of the reserve.

[6] Available at http://anps-canberra.asn.au/site_old/index.php/gatherings-category-list/wednesday-walks/plant-lists

Fig. 4. Wednesday Walkers identifying a plant, September 2009. Photo: J Geue.

5.3 Frogwatch

Frogwatch was established in 2002 to organise and maintain a community frog monitoring program in the ACT and surrounding region. It is managed by the Ginninderra Catchment Group through funding from the ACT Government and involves a census of frogs (FrogCensus) in October each year at a range of designated locations across the ACT region.

Five frog census sites are located on the lower slopes of Black Mountain, three of them dams in the north and west of the reserve and two of them semi-permanent pools of water on creeks draining from the eastern side (see Fig. 5 and Table 4). Fifty-seven frog surveys have been carried out at these sites from October 2009 to October 2017, approximately half of them by members of the Friends of Black Mountain led by Linda Beveridge with observers Debbie Cameron, Baeckea, Cornea and Don Driscoll, Eyal Lebedinsky, Gale Lindfield, Margaret Strong, Margaret Webber and Nick Shore. Other contributors have been Anke Maria Hoefer and Loren Howell as leaders and observers Paul Doyle, Juliet Gribaldi, Sarah and Roger Hnatiuk, Helen King, Penny Lilley, Sebastin Queisser, Stuart Rae, Nick Shore and John Travers (Hoefer 2018; Beveridge 2018a). The surveyors have recorded seven of the eight frog species known to occur on Black Mountain (see Osborne and Hoefer 2018).

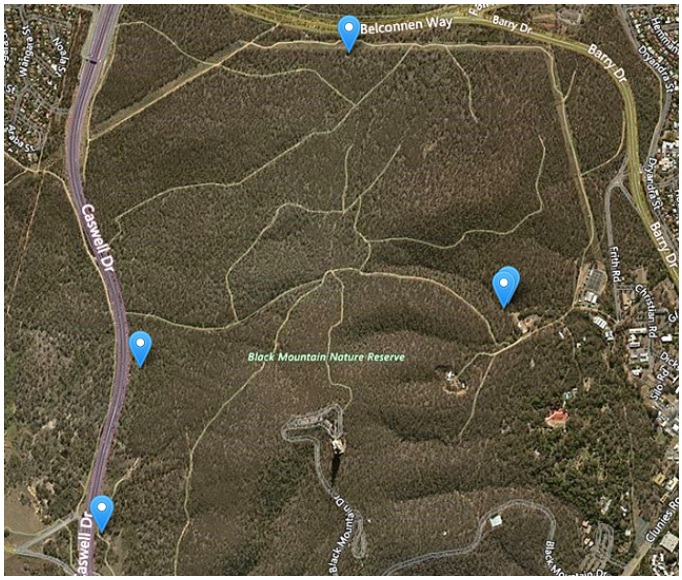

Fig. 5. Location of Frogwatch sites on Black Mountain.

Table 4. Frogwatch surveys on Black Mountain (Hoeffer 2018)

Site Number	Location	No. of surveys	Years	No. of species recorded
BMT100	Dam near the Swamp Track on the western side of the reserve.	17	2006–2017	6
FBM200	Semi-permanent pool on a creek between the road to the ANU quarry (a continuation of Frith Road) and the start of the Kid's Lookout Track.	10	2009–2017	7
FBM300	Semi-permanent pool on creek near the north-west corner of the ANBG landscape storage area, off Frith Road.	9	2009–2017	5
FBM400	Dam near the Powerline Track in the north of the reserve.	13	2009–2017	5
FBM500	Dam near the Woodland Track on the south-west side of the reserve.	8	2012–2017	5

5.4 Batwatch

In 2013 the ACT Government provided funds to Michael Pennay for the Australasian Bat Society to run Batwatch surveys in the ACT, with the objective of increasing public awareness of bats by involving people in surveys for the animals. Seven microbat species were recorded on Black Mountain during the survey there (Evans 2018b).

5.5 ACT Centenary Bioblitz[7]

To help celebrate the centenary of Canberra, the Molonglo Catchment Group in partnership with the Atlas of Living Australia organised a three-day event on 25–27 October 2013 for scientists, naturalists and interested members of the public to record a snapshot of Black Mountain's biodiversity. It aimed to be a "fun event" that would inspire participants to protect and conserve the ACT's native species as well as raise awareness of "the incredible variety of life that can be found on our doorsteps". A series of "fast and intensive" surveys was carried out to look for and record "moths, bats, birds, frogs, reptiles, mammals" and plants, and involved over 450 people. The leaders included Stephen Skinner and Woo O'Reilly (macroinvertebrates; algae), Tony Wood (orchids), Michael Mulvaney and Kirsten Velthuis (plants), Sarah Sharp and Clare Kerr (vegetation), Doug Laing, Lonneke and Clare Kerr (birds), Darren LeRoux and Michael Pennay (bats), Ross Bennett (reptiles), Eyal Lebedinsky (frogs), Glenn Cocking (moths), Kim Pullen (insects) and Stuart Harris (peacock spiders). Just over 800 survey sightings resulted in 322 different species being recorded, including moths and a peacock spider that had not previously been recorded from Black Mountain, seven species of microbat and seven rare plant species. All the data collected were lodged in the Atlas of Living Australia.

5.6 Canberra Nature Map

The website Canberra Nature Map (http://canberra.naturemapr.org) was established by computer software engineer Aaron Clausen (Clausen undated) to allow members of the public to upload their photographic images of plants and animals taken in the ACT and surrounding areas. Initially established as a means of letting anyone report sightings of rare plants, it quickly became a popular site for uploading photographs of any plants (and later, animals) people observed while walking in the ACT's reserves (Bedingfield 2017). Individuals with expertise in particular reserves or groups of organisms

[7] Information from a poster advertising the event, ANBG Library, accessed February 2018; web pages http://actlandcare.org.au/node/1303, https://blog.csiro.au/citizen-scientists-bring-more-critters-online and https://www.ala.org.au/uncategorised/act-centenary-bioblitz/, accessed 17 March 2018; and from a copy of a public talk presented at the Australian National Botanic Gardens on 20 February 2014.

were designated as moderators to help ensure all species photographed were correctly named. Black Mountain Nature Reserve and adjacent areas were among the many places where people started taking photographs and uploading them.

From the time Canberra Nature Map went live in early October 2013 to 5 March 2018 at least 51 people had uploaded around 2360 photographic records of the flora and fauna in Black Mountain Nature Reserve and the ANBG Bushland Precinct (Purdie unpublished–c). Around 89% of the photos are of flowering and other vascular plants, at least 65% of which are orchids. While the latter largely reflects deliberate searches for orchids from spring 2015 to spring 2016 as part of a fire and orchid citizen science project (see section 5.8), opportunistic photos of orchids have been a strong feature of Canberra Nature Map records on Black Mountain from the website's start. The plant photographs include the first record on Black Mountain of the orchid *Diuris pardina* in 2014, and in 2016 assisted in the relocation of *Leucopogon microphyllus* var. *pilibundus* (Fig. 6), a shrub species that until then had not been recorded in the reserve since 1980. The remaining photos include invertebrates (6% of photos), non-vascular plants (fungi, lichens, liverworts and mosses; 3%), and reptiles, birds and mammals (<1% each). Individuals who have made major contributions of plant photos from Black Mountain include Ian Baird, Aaron Clausen, Peter Coyne, Jason Cummings, Matthew Mullaney, Michael Mulvaney, Mrs Ryl Parker, Ken Thomas, Jennie Widdowson and Betty and Don Wood.

Fig. 6. *Leucopogon microphyllus* var. *pilibundus* occurs in only one localised area on Black Mountain. Photo: R Purdie.

5.7 Friends groups

The Friends of Black Mountain (FoBM) established three vegetation monitoring sites in Black Mountain Nature Reserve as part of the ACT Vegwatch program (see Sharp and Gould 2014). Two 20 m × 50 m plots were set up on the north-eastern lower slopes in 2013 and a third plot on the south-eastern slopes above ANBG in 2014. The purpose of the work is to monitor the condition of the vegetation and record changes in vegetation structure and floristic composition over time, especially after fire. Since being established, the plots have been measured annually by FoBM volunteers under the guidance of local botanists knowledgeable about the area's plants, with 23 members being involved (Beveridge 2018b). Training sessions have also been run prior to the monitoring in some years to increase participants' plant recognition skills. The data collected includes the total number of tree and taller shrub species, structural diversity of the vegetation, estimates of cover/abundance for each structural element, measures of tree, shrub and ground layer cover, total floristics and estimates of each species' abundance in a 20 m × 20 m subplot, and overall habitat condition.

To date the south-east site has been the most informative, as the plot was established in an area subject to a fuel reduction burn a couple of weeks after the vegetation indicators were first measured and recorded. Monitoring has tracked the recovery of the vegetation in the plot, including identifying fire sensitive species that regenerate only through post-fire seed germination and the time being taken for

regrowth and seedlings to become sexually mature and start replenishing the soil/canopy seed store (Doherty 2018; Friends of Black Mountain unpublished).

In 2016 the Plant Science Group of the Friends of ANBG commenced a three-year study of Fan Grevillea, a rare plant in the ACT (see Mulvaney 2018a) with two populations on Black Mountain (both located on ANBG land). The objectives were to record information that would facilitate appropriate management of the species and help ANBG make an *ex situ* seed store of it. The first two years of data established the total size and size-structure of each population, and their levels of flowering, seed set and natural seedling recruitment. The data also showed that fire frequency appears to be the key management issue, as plants are killed by fire and require at least four years to reach sexual maturity and start producing seed (Purdie 2017).

5.8 Orchids

Black Mountain has been recognised as a 'hot spot' for ground orchids since at least the late 1970s (Shorthouse 1979). In the decades since, orchid enthusiasts have significantly increased knowledge about the area's orchid diversity and the locations, distribution and flowering patterns of species in the reserve and adjacent areas. Frank Bullen carried out an orchid census and phenological survey at eight sites in the north-west of the reserve from 1997 to 2005, examining the effect of factors such as photoperiod, ambient temperature and rainfall on flowering time and flower abundance (Bullen 2002, 2005). Jean Egan had started to record the flowering times of Black Mountain orchid species in 1992. Aware of other people interested in the local orchids, in January 2001 she established the email group OrchidGroupACT to provide the opportunity for members to look for and record information about species on Black Mountain and other places in the ACT (Egan 2017). John Busby began databasing all the group's location and flowering time records in early 2018 to provide better access to the wealth of information they provide.

In 2012 Egan and colleague Tony Wood were asked by the ACT Department of Territory and Municipal Services (TAMS) to mark the locations of all orchid species on Black Mountain as part of planning for the ACT's Centenary Trail (Egan 2017, 2018). The locations were added to the government's geographic information system so they can be taken into account when relevant authorities plan the location and timing of fuel reduction burns in the reserve (see section 4.2). The Egan and Wood map was also used to help compile a list of rare plant species in the territory (Mulvaney 2014).

Concerns about the impact of fuel reduction burns on the orchids of Black Mountain and adjacent sandstone areas (Aranda Bushland, Bruce Ridge, O'Connor Ridge and Gossan Hill) led to ACT Government Conservation Research ecologists Michael Mulvaney and Julian Seddon establishing a citizen science project in 2015. Its objectives were to improve understanding of the relationship between orchid presence and abundance and fire histories in the Black Mountain Sandstone area, convey the understanding gained to project participants, and relate the information to improved fire management (Mulvaney 2016). Volunteers were asked to 'adopt' one or more point-locations selected by Mulvaney and Seddon to sample the range of fire history in the area, including matching recently burnt and unburn locations. From spring 2015 to spring 2016 the volunteers visited their adopted points twice in each spring (October and November) and once each in summer and autumn. They spent one hour searching for orchids within a 50 m radius of each point, photographed every species seen, then uploaded the images onto Canberra Nature Map (see section 5.6 above) together with an estimate of each species' abundance class. A table of orchid flowering times from data collected by Cath Busby through systematic orchid surveys since 2014, in nearby Aranda Bushland and the Mt Painter Wildflower Triangle, was used as background information to help volunteers anticipate what species might be in flower during each monitoring period. Thirty-two volunteers participated in the project (Mulvaney 2016). The study showed that two rare orchid species on Black Mountain are likely to decline if their habitat is subject to frequent fires, while two other rare species are likely to decline if fire is excluded from their habitat (see Mulvaney 2018a).

6. Conclusion

Current scientific knowledge about Black Mountain is the legacy of numerous scientists who have been collecting specimens and data there since the 1920s as well as the 'citizen science' activities of many members of the Canberra community since the 1960s. Their collective efforts have resulted in Black Mountain's biota probably being more comprehensively studied and documented that any other area of comparable size in the ACT and reflect a combination of key collecting and research institutions being located on the footslopes of the area (Pullen 2018b, Purdie 2018a) and its accessibility and high level of visitation by local citizens. While the research has resulted in numerous publications in ecological and other scientific journals, much of the monitoring carried out by ACT Government scientists and local citizens is out of the public eye and its nature and extent often not appreciated.

Some of the unpublished data from Black Mountain provide an opportunity for tracking ecological changes there. For example, in the Smith's Paddock area changes to the structure of its vegetation relating to Burgan (*Kunzea ericoides*) could be examined by drawing on data from the unpublished thesis of Pavlovic (1982), Sharp's monitoring data from 1993 to 2001 (section 4.2) and repeat measurements in the area today, and help shape future management objectives there. Ward's flowering and fruiting calendar (section 4.2) provides a phenological benchmark for the mid-1970s to early 1980s. A similar study now as a citizen science project using Canberra Nature Map and organised by ACT Government scientists could provide information about the impact of climate change on the phenology of Black Mountain's flora.

Community involvement in citizen science on Black Mountain covers a wide range of flora and fauna groups. The level of involvement means many local people are very knowledgeable about the area and have both a strong sense of attachment to it and an interest in how it is managed. Canberra Nature Map has become an important repository for citizen science observations, with the records providing information about the presence, location, abundance and flowering/breeding times of species located in the area. These data may assist in tracking future changes of attributes such as its biodiversity in relation to management or environmental and climatic factors. The orchid/fire citizen science project (section 5.8) provides a model of how the interest and enthusiasm of community members can be harnessed to expand scientific knowledge about the ecology of any area and help contribute to informed management practices.

The Black Mountain area remains a fertile location for continued research effort, utilising and adding to the existing knowledge and understanding of its biota and ecology, that will help strengthen evidence-based management in the coming decades.

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Appendix 1

List of people known to have collected insects on Black Mountain

Name

The names of collectors are derived from specimens from Black Mountain that have been databased (Purdie unpublished–b) and from Upton (2018) and Edwards (2018). Names followed by an asterisk (*) were either professional or support staff at the Australian National Insect Collection (ANIC) (Upton 1997, 2018). The list is unlikely to be comprehensive because of the small proportion of ANIC collections that have been databased. The list includes entomologists who have made major collections from the area as well as people who have made casual, sometimes one-off collections.

Year

The dates shown in normal font are the period over which the person was known to be actively collecting insects, and is largely derived from Upton (1997, 2018) with additional information from Edwards (2018); data are not available to indicate the years in which they collected specimens from Black Mountain. Dates in italics are based on the collecting dates shown on specimens from Black Mountain that have been databased (Purdie unpublished–b); these collectors may well have collected more specimens from Black Mountain in other years.

Name	Year
Abbey, HM*	*1982*
Allen, PG	*1971*
Allen, W*	?
Angus, RB	*1965*
Atkins, AF	*1980*
Baker, GJ	?
Ballard, B	*1991*
Barnes, HM*	*1930–1931*
Barnett, NJ	*1996–1997*
Barrett, RA*	*1969, 1980*
Bartell, RJ	?
Batley, M	*2006*
Beens, HM	*1992*
Berg, RY	*1972*
Bickel, DJ	*1984*
Billen, J	*1987*
Braby, M*	1990s
Britton, EB*	1964–1977
Brooks, CG	*1968, 1970*
Brooks, EM*	?
Brown, MV	*1980*
Bruce, W	*1929–1930*
Butcher, AD	*1930-36*
Bywater, J	*1967*
Calaby, JH*	1945–1950
Calder, AA*	*1981–2000*
Cameron (née Cane), HM*	?
CM	*1951–1957*
Campbell, KG	*1949*
Campbell, TG*	1929–1969
Cardale, J*	1967–2002
Carne, DP	*1957, 1976*
Carne, PB*	1946–1986
Carver (née Fielding), M*	1962–1979, *1986*
Cassis, GA*	*1988*
Chinnick, LJ*	1944–1975
Cocking, G*	2000s
Colless, DH*	1947, 1960–1987
Common, IFB*	1948–1982
Cranston, P*	1987–
Crook, F	*1980*
Crosland, M	*1985*
Crozier, R	*1962, 1975*
Currie, GA*	*1930–34*
Dahms, E	?
Day, MF*	2000s
De Barro, P	?
Devonshire, J	*2000*
Dowse, J	*1991*
Doyen, J	*1982*
Dressler, W*	*1987, 1991*
Eastop, VF	*1990*
Edwards, ED*	1970–
Euibersou, RM	*1972*
Evans, JW*	1928–1935
Farrow, R*	*1989, 1991*
Feehan, JE*	?
Ferguson, D	*1976*
Fitzgerald, M	?
Fletcher, M	?

Name	Year
Fuller, ME (later Kipps)*	1929–1938
FW	*1953*
Fyfe, RV	*1935–1939*
Gauld, ID	?
Gay, FJ*	1933–1970
Gay, FS	*1933, 1959*
Gibson, G	*1999*
Graham, LF*	1929–1932
Gray, MR	*1987*
Greaves, T*	1930–1967
Green, J*	*1979*
Gullan, P*	1983–
Hall, GP	*1976–1977*
Halliday, RB*	1981–
Harley, K	*1975*
Harris, S	*2012*
Harvey, MS*	*1984*
HDB	?
Helms, K	*1975–1976*
Hickman	*1944*
Hill, GF*	1926–1941
HM & KO	*1971–1972*
Hoare, RJB	1990s
Hobern, D	*2011–2016*
Holdaway, FG*	1926–1928
Holm, E*	*1976*–1980s
Horak, M*	1982–
Houston, TF	*1968*
Howell, RW	*1982*
Hughes, WK	*1930*
Imai, HT	*1985*
Irwin, ME	*1988*
James, J	*1984*
James, LM*	*1959*
Johnson, NF	*1987*
Kelsey, L	*1979*
Kent Hughes, WP (later Radford)*	1928–1929
Key, KHL*	1936–1976
Khan, SM	*1970–1976*
Khinzaw, O	*1998, 2001*
Kohout, R*	*1973*–early 1980s
Lambkin, C*	*1988, 2002*
Lawrence, JF*	1977–1990
Lewis, M	*1987*
Lewis, RC*	1950s–1980s
Liepa, ZR*	*1957, 1986*

Name	Year
Linstar, ?	?
Loetr, T	*1986*
Loneragan	*1950*
Lowery, BB	*1959, 1999*
Mackerras, IMC*	1928–1947
Mackerras, MJ*	1930–1947
Mahon, JA*	?
Masner, L	?
McAlpine, DK	*1979*
McCorquodale, DB	*1987*
McInnes, RS*	1950s–1980s
Misko, S*	*1969, 1973*
Mitchell, NJR	*1968*
MMO	*1971*
Moore, BP*	*1969*
Moran, RJ*	*1983*
Morris, D	*2000*
Mound, LA*	*1994, 2003*
Naumann, ID*	1977–1982
Newton, A	*1980*
Nicholson, AJ*	1930–1960
Nielsen, ES*	1982–2001
Norris, KR*	1937–1979
Noyes, JS	?
O'Dowd, D	?
Paramonov, SJ*	1947–1959
Peters, BC	?
Pullen, KR*	*1966, 1984*
PW, HM & KO	*1971–1972*
Rafferty, WJ*	*1930–1938*
Rait, WL	*1934*
Rangsi, TV*	1970s–2000s
Rao, S	*2008*
RDB	*1936*
Readshaw, L	*1986*
Reed, CAM	*1988, 1992*
Reed, EM	*1969*
Rentz, DCF*	1977–2000
Riek, EF*	1945–1976
Rodway	*1935*
Sackelarion, G	*1953*
Sadler (née Janssen), R*	?
Sayers, F	*1952*
Shattuck, SO*	1988, 1991–
Short, JRT	*1982*
Shorthouse, DJ	?
Simmons, JM	*1969–1970*
Sinclair, P	?
Slipinski, A*	*2002*

Name	Year
Smith, GT	*1980*
Smithers, CN	*1960*
Speechley, AE	*1966*
Squires, N	*2001*
Staautmanis, J*	?
Story, M*	1970s
Straatman, R*	1950s
Strautman[8], RS*	?
Taplin, IC	*1970*
Tarman, G	*2009*
Taylor, KL*	1951–1991
Taylor, RW*	1966–1990
Tillyard, RJ*	1928–1934
Tonnoir, AL*	1929–1940
Upton, MS*	1959–1983
Vestjens, W	*1956*
Wade, AM*	*1930*
Wallace, MMH*	1946–1985
Wallman, JF	?
Ward, JB	*1981*
Ward, PS	*1999*
Watson, JAL*	1967–1993
Webber, LG	*1936*
Weir, TA*	1976–2002
Wetherley, AHW*	1950s–1980s
Wilson, H	*1978*
Wilson, N	?
Zimmerman, EC*	1973–1982

[8] Possibly a misspelling of Straatman

Appendix 2

Species for which Black Mountain is the type locality

The tables below show the scientific name used for the newly described species at the time of publication, and the year of publication. Names no longer accepted as the current scientific name are marked with [#]. The list excludes species for which the Australian National Botanic Gardens is the type locality.

(a) Plant species – holotypes

Data sources. Lichens: *Flora of Australia* volumes 54, 55, 56A, 57, 58A text searches, May 2017. Vascular plants: Australian Plant Name Index (APNI; https://biodiversity.org.au/nsl/services/APNI) and Australian National Herbarium Specimen Information Register (ANHSIR; www.anbg.gov.au/cgi-bin/anhsir) database searches, April 2017.

Family	Scientific name	Year
Lichens		
Lecanoraceae	*Lecanora pseudogangaleoides*	1995
Parmeliaceae	*Parmelia neorimalis*[#]	1983
Vascular plants		
Caryophyllaceae	*Stellaria multiflora* subsp. *collaris*	2012
Orchidaceae	*Arachnorchis atrovespa*[#]	2008
Orchidaceae	*Bunochilus umbrinus*[#]	2006
Orchidaceae	*Calochilus montanus*[#]	2006
Orchidaceae	*Calochilus platychilus*	2008
Orchidaceae	*Calochilus therophilus*	2006
Orchidaceae	*Corunastylis clivicola*[#]	2007
Orchidaceae	*Corunastylis cornuta*[#]	2008
Orchidaceae	*Diuris nigromontana*	2008
Orchidaceae	*Stegostyla ustulata*[#]	2007

(b) Invertebrate species – lectotypes (shaded in grey) and holotypes

Data source. Australian Faunal Directory (https://biodiversity.org.au/afd/home) database search, March 2017 and Pullen (2018b).

Order	Family	Scientific name of type specimen	Year
Spiders (Class Arachnida)			
Araneae	Salticidae	*Maratus calcitrans*	2012
Insects (Class Insecta)			
Blattodea	Blattidae	*Platyzosteria (Melanozosteria) capitolina*[#]	1968
Blattodea	Ectobiidae	*Johnrehnia solida*	2000
Blattodea	Ectobiidae	*Robshelfordia biramustyla*	1991
Blattodea	Kalotermitidae	*Calotermes (Glyptotermes) neotuberculatus*[#]	1933
Blattodea	Termitidae	*Hamitermes xylophagus*[#]	1935
Coleoptera	Buprestidae	*Castiarina xystra*	1993
Coleoptera	Carabidae	*Adelotopus montisatri*	1997
Coleoptera	Carabidae	*Anomotarus (Anomotarus) moorei*	2012
Coleoptera	Carabidae	*Euthenarus bicolor*	1985
Coleoptera	Carabidae	*Microlestodes (Cyclolestodes) ovatus*	1987
Coleoptera	Carabidae	*Pseudagonica minuta elongata*	2012
Coleoptera	Carabidae	*Sphallomorpha costalis*	1992
Coleoptera	Carabidae	*Sphallomorpha ruficollis*	1992
Coleoptera	Cerambycidae	*Paratesta chiangi*[#]	1993

Order	Family	Scientific name of type specimen	Year
Coleoptera	Ciidae	*Cis canberrae*	2016
Coleoptera	Ciidae	*Cis eremicus*	2016
Coleoptera	Cleridae	*Crobenia irwini*	2003
Coleoptera	Dermestidae	*Anthrenocerus intricatus*	2000
Coleoptera	Dermestidae	*Anthrenocerus piliatus*	2000
Coleoptera	Elateridae	*Paracardiophorus assimilis*	1939
Coleoptera	Geotrupidae	*Elephastomus meraldus*	1965
Coleoptera	Histeridae	*Chlamydopsis lawrencei*	2003
Coleoptera	Scarabaeidae	*Anoplognathus pindarus*	1957
Coleoptera	Scarabaeidae	*Gnaphalopoda carnei*	1987
Coleoptera	Scarabaeidae	*Liparetrus pectinatus*	1980
Coleoptera	Scarabaeidae	*Telura petiolata*	1987
Coleoptera	Scirtidae	*Austrocyphon aculeatus*	2013
Coleoptera	Scirtidae	*Nanocyphon australicus*	2013
Coleoptera	Scirtidae	*Nothocyphon ypsilon*	2015
Coleoptera	Scirtidae	*Peneveronatus actensis*	2009
Coleoptera	Scirtidae	*Prionocyphon uncatus*	2016
Coleoptera	Staphylinidae	*Leptostibina blackmontis*	2015
Coleoptera	Staphylinidae	*Nasutiphilus flavus*	1970
Coleoptera	Staphylinidae	*Nasutiphilus niger*	1970
Diptera	Agromyzidae	*Liriomyza cassiniae*	1977
Diptera	Agromyzidae	*Liriomyza impolita*	1977
Diptera	Agromyzidae	*Phytobia optabilis*	1977
Diptera	Apioceridae	*Apiocera similis*	1953
Diptera	Bibionidae	*Dilophus tetrascolus*	1982
Diptera	Cecidomyiidae	*Catotricha fraternal*[#]	2001
Diptera	Ceratopogonidae	*Culicoides sigmoidus*	1963
Diptera	Ceratopogonidae	*Forcipomyia (Lepidohelea) bullata*	1987
Diptera	Ceratopogonidae	*Forcipomyia (Lepidohelea) parvicrater*	1987
Diptera	Ceratopogonidae	*Forcipomyia (Metaforcipomyia) colona*	1987
Diptera	Ceratopogonidae	*Forcipomyia (Pedilohelea) proavia*	1987
Diptera	Ceratopogonidae	*Lanatomyia miles*	1974
Diptera	Ceratopogonidae	*Leptoconops riverinaensis*	1966
Diptera	Ceratopogonidae	*Monohelea harpagonifera*[#]	1972
Diptera	Chamaemyiidae	*Leucochthiphila photophila*	1996
Diptera	Chamaemyiidae	*Pseudoleucopis benefica*	1930
Diptera	Chamaemyiidae	*Pseudoleucopis nigromontana*	1996
Diptera	Chamaemyiidae	*Pseudoleucopis trichaeta*	1996
Diptera	Chironomidae	*Tanytarsus commoni*	1973
Diptera	Chloropidae	*Lioscinella sabroskyi*[#]	1982
Diptera	Chloropidae	*Lipara australis*	1940
Diptera	Chloropidae	*Tricimba lata*	1993
Diptera	Dolichopodidae	*Austrosciapus actensis*	1994
Diptera	Dolichopodidae	*Mesorhaga canberrensis*	1994
Diptera	Dolichopodidae	*Sympycnus claudicans*	1932
Diptera	Dolichopodidae	*Systenus australis*	1986
Diptera	Dolichopodidae	*Thrypticus australis*	1986
Diptera	Empididae	*Anaclastoctedon prionton*	2010
Diptera	Fanniidae	*Fannia capitalis*	1977
Diptera	Heteromyzidae	*Diplogeomyza conformis*	1967
Diptera	Heteromyzidae	*Zentula vittata*	1985
Diptera	Limoniidae	*Molophilus (Austromolophilus) warriuka*	1992

Order	Family	Scientific name of type specimen	Year
Diptera	Muscidae	*Atherigona (Atherigona) collessi*	1986
Diptera	Muscidae	*Atherigona alpha*	1981
Diptera	Pipunculidae	*Eudorylas cernuus*	2002
Diptera	Pipunculidae	*Eudorylas montivagus*[#]	1993
Diptera	Platypezidae	*Lindneromyia austraquila*	1994
Diptera	Platystomatidae	*Duomyia capitalis*	1973
Diptera	Platystomatidae	*Duomyia personata*	1973
Diptera	Psychodidae	*Psychoda squamipleuris*	1953
Diptera	Pyrgotidae	*Adapsona commoni*	1958
Diptera	Pyrgotidae	*Epicerella nigrescens*[#]	1958
Diptera	Pyrgotidae	*Facilina commoni*	1958
Diptera	Pyrgotidae	*Facilina tertia*	1958
Diptera	Pyrgotidae	*Frontalia noctua*	1958
Diptera	Pyrgotidae	*Frontalia tonnoiri*	1958
Diptera	Pyrgotidae	*Osa commoni*	1958
Diptera	Pyrgotidae	*Osa simplex*	1958
Diptera	Pyrgotidae	*Osa sinclairae*	1958
Diptera	Scatopsidae	*Colobostema bihastatum*	1971
Diptera	Scatopsidae	*Colobostema diversum diversum*	1971
Diptera	Scatopsidae	*Colobostema retusum*	1971
Diptera	Scatopsidae	*Diamphidicus australis*	1971
Diptera	Scatopsidae	*Reichertella digitata*	1971
Diptera	Scenopinidae	*Paratrichia lobosa*	1969
Diptera	Sphaeroceridae	*Leptocera (Biroina) subsinuata*[#]	1973
Diptera	Sphaeroceridae	*Leptocera (Pseudocollinella) difficilis*[#]	1973
Diptera	Tachinidae	*Anagonia commoni*	2012
Diptera	Tachinidae	*Anagonia minor*	2012
Diptera	Tachinidae	*Anagonia norrisi*	2012
Diptera	Tachinidae	*Anagonia zentae*	2012
Diptera	Tachinidae	*Austronilea livida*	1967
Diptera	Tachinidae	*Carcelia (Euryclea) flavitibia*	1985
Diptera	Tachinidae	*Chetogaster canberrae*	1954
Diptera	Tachinidae	*Froggattimyia lasiophthalma*[#]	1934
Diptera	Tachinidae	*Geraldia biseta*	1992
Diptera	Tachinidae	*Microtropesa canberrae*	1951
Diptera	Tephritidae	*Paraspathulina apicomacula*	1996
Diptera	Tephritidae	*Tephritis pantosticta*[#]	1996
Diptera	Therevidae	*Agapophytus antheliogynaion*	2001
Diptera	Therevidae	*Agapophytus chrysosisyrus*	2001
Diptera	Therevidae	*Anabarhynchus plumbeoides*	2001
Diptera	Therevidae	*Laxotela gaimarii*	1999
Diptera	Tipulidae	*Leptotarsus macquartii flavolateralis*	1944
Diptera	Trichoceridae	*Nothotrichocera cranstoni*	1994
Embioptera	Australembiidae	*Metoligotoma reducta ingens*[#]	1936
Hemiptera	Cicadellidae	*Rosopaella evansi*	1983
Hemiptera	Cicadellidae	*Rosopaella magnata*	1983
Hemiptera	Cicadellidae	*Rosopaella praeda*	1983
Hemiptera	Cixiidae	*Chidaea dayi*	2000
Hemiptera	Cixiidae	*Ronaldia fennahi*	2000
Hemiptera	Eriococcidae	*Lobimargo donaldsoni*	2011
Hemiptera	Psyllidae	*Acizzia pendulae*	1999
Hemiptera	Psyllidae	*Glycaspis (Synglycaspis) immaceria*	1970

Order	Family	Scientific name of type specimen	Year
Hemiptera	Psyllidae	*Hyalinaspis nigricamera*	1962
Hemiptera	Psyllidae	*Hyalinaspis pallidinota*	1962
Hemiptera	Psyllidae	*Hyalinaspis semispherula*	1962
Hemiptera	Psyllidae	*Hyalinaspis vitreipelta*	1962
Hemiptera	Tingidae	*Australocader kerzhneri*	1997
Hymenoptera	Braconidae	*Chelonus fischeri*	1994
Hymenoptera	Braconidae	*Diolcogaster adiastola*	1999
Hymenoptera	Braconidae	*Jarra phoracantha*	1994
Hymenoptera	Braconidae	*Myosoma rufescens*[#]	1993
Hymenoptera	Braconidae	*Phanerotomella obscura*	2014
Hymenoptera	Braconidae	*Promicrogaster dissors*[#]	1965
Hymenoptera	Braconidae	*Simplicibracon nigritarsus*	1993
Hymenoptera	Colletidae	*Hylaeus (Planihylaeus) daviesiae*	1981
Hymenoptera	Colletidae	*Hylaeus (Planihylaeus) probligenatus*	1981
Hymenoptera	Colletidae	*Hyphesma federalis*	1975
Hymenoptera	Crabronidae	*Rhopalum (Rhopalum) grahami*	1957
Hymenoptera	Dryinidae	*Epicerella naumanni*[#]	1991
Hymenoptera	Embolemidae	*Ampulicomorpha australis*	1996
Hymenoptera	Eulophidae	*Goetheana rabelaisi*	2005
Hymenoptera	Formicidae	*Iridomyrmex infuscus*	2011
Hymenoptera	Gasteruptiidae	*Pseudofoenus iqbali*	2002
Hymenoptera	Ichneumonidae	*Australochus clypeator*	2004
Hymenoptera	Ichneumonidae	*Casinaria hesperiophaga*	1988
Hymenoptera	Ichneumonidae	*Lycorina canberrae*	1984
Hymenoptera	Ichneumonidae	*Nebostenus terebratus*	1984
Hymenoptera	Ichneumonidae	*Neolophron canberrai*	1984
Hymenoptera	Ichneumonidae	*Xylostenus curtus*	1984
Hymenoptera	Mymaridae	*Boccacciomymar decameron*	2007
Hymenoptera	Peradeniidae	*Peradenia micranepsia*	1985
Hymenoptera	Pompilidae	*Idiaporina canberra*	1974
Hymenoptera	Pompilidae	*Psoropempula nulgarra*	1975
Hymenoptera	Pompilidae	*Psoropempula puna*	1975
Hymenoptera	Scelionidae	*Embidobia australica*	1939
Hymenoptera	Scelionidae	*Embidobia metoligotomae*	1939
Hymenoptera	Scelionidae	*Scelio unidentis*	2001
Hymenoptera	Torymidae	*Epimegastigmus quinquesetae*[#]	1934
Lepidoptera	Bucculatricidae	*Ogmograptis barloworum*	2012
Lepidoptera	Bucculatricidae	*Ogmograptis maxdayi*	2012
Lepidoptera	Bucculatricidae	*Ogmograptis paucidentatus*	2012
Lepidoptera	Coleophoridae	*Coleophora albiradiata*	1996
Lepidoptera	Elachistidae	*Elachista (Atachia) coalita*	2011
Lepidoptera	Elachistidae	*Elachista (Atachia) floccella*	2011
Lepidoptera	Elachistidae	*Elachista (Elachista) platina*	2011
Lepidoptera	Elachistidae	*Elachista (Elachista) sandaraca*	2011
Lepidoptera	Lophocoronidae	*Lophocorona melanora*	1975
Lepidoptera	Oecophoridae	*Phthonerodes peridela*	1964
Neuroptera	Coniopterygidae	*Neosemidalis (Neosemidalis) longiscapa*	1972
Thysanoptera	Phlaeothripidae	*Adelothrips australis*[#]	1974
Thysanoptera	Phlaeothripidae	*Allothrips hamideae*	2007
Thysanoptera	Phlaeothripidae	*Bocathrips okajimai*	2010
Thysanoptera	Phlaeothripidae	*Carientothrips reedi*	1974
Thysanoptera	Phlaeothripidae	*Deplorothrips capitalis*	2016

Order	Family	Scientific name of type specimen	Year
Thysanoptera	Phlaeothripidae	*Deplorothrips minaei*	2016
Thysanoptera	Phlaeothripidae	*Hoplandrothrips hemiflavus*	2013
Thysanoptera	Phlaeothripidae	*Jacotia glyptus*	1995
Thysanoptera	Phlaeothripidae	*Minaeithrips aliceae*	2007
Thysanoptera	Phlaeothripidae	*Podothrips websteri*	2007
Thysanoptera	Phlaeothripidae	*Priesneria peronis*	2007
Thysanoptera	Phlaeothripidae	*Psalidothrips taylori*	1986
Thysanoptera	Phlaeothripidae	*Strepterothrips barbatus*	2015
Thysanoptera	Phlaeothripidae	*Zemiathrips triseta*	2002
Thysanoptera	Thripidae	*Anaphothrips chortinus*	2009
Thysanoptera	Thripidae	*Anaphothrips exocarpoides*	2009
Thysanoptera	Thripidae	*Anaphothrips parsonsiae*	2009
Thysanoptera	Thripidae	*Anaphothrips westringiae*	2009
Thysanoptera	Thripidae	*Lomatothrips pinopsidis*	2006