Cumberland Plain Woodland ecology then and now: interpretations and implications from the work of Robert Brown and others

Doug Benson and Jocelyn Howell

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By the time Robert Brown visited western Sydney (1802–1805), its vegetation was already beginning to be affected by settlers' activities. The Cumberland Plain Woodland that occurred on the clay soils has now been extensively cleared and long-term management of remnants for species conservation is of high priority. Robert Brown's collections in the area, together with descriptions by Atkinson, Cunningham and other writers, provide us with valuable information on the vegetation and its floristic composition. Supported by recent site monitoring at Mount Annan Botanic Garden at Campbelltown, we interpret this information in the light of current ecological knowledge and conclude that:

- Woodland structure is variable in the short term; therefore seeking to conserve structure exactly as described in the historical literature is not necessarily appropriate.
- While the historical literature provides evidence of the broad floristic composition of the Cumberland Plain area overall, it does not provide sufficient detail on individual sites; future management of specific sites must therefore be based on current data.
- The evidence suggests relatively few species have become extinct overall, possibly because many species appear to be relatively long-lived, and have mechanisms to survive drought, fire and grazing, though not soil alteration.
- Many species, however, are now distributed patchily in localised remnants and rare species are not clustered in a predictable way; species diversity is therefore likely to be lost if further clearing of remnants occurs.

Introduction

During his botanical collecting in the Sydney area (1802–1805) Robert Brown visited a number of sites in western Sydney. In particular he made a number of trips to the Hawkesbury River around *Greenhills* (Windsor) and the nearby Grose River, and one trip to the *Cowpastures* (Camden area). During these trips Brown would have passed through areas of Cumberland Plain Woodland which occurred extensively on the clay soils on the Wianamatta Shale geology of much of western Sydney. Even at this early stage in European settlement though, the native vegetation was already being affected by the settlers' activities — the clearing of the floodplains of the Hawkesbury River for agriculture and grazing of stock on the grassy understorey of the nearby Cumberland Plain Woodland.

Cumberland Plain Woodland once covered an estimated area of about 125 000 hectares on the clay soils of western Sydney, extending north-west to Kurrajong and south-west to Picton (National Parks and Wildlife Service 2000). It has been extensively cleared by two centuries of agriculture and urban development, and is now listed under the NSW *Threatened Species Conservation Act* as an Endangered Ecological Community. The long-term management of remnants is of high priority.

This paper looks at the species components and ecology of Cumberland Plain Woodland as described by early writers including Robert Brown, and how this compares with the composition and structure of remnants based on recent site monitoring at Mount Annan Botanic Garden at Campbelltown. We are interested in how it may have looked to the early botanical visitors, what we can infer from the 19th century record, how the ecological components interact today, and the implications for conservation and management.

General overview of Cumberland Plain Woodland and western Sydney vegetation

The most recent view of western Sydney vegetation, that of the National Parks and Wildlife Service (2000), has been based mainly on analysis of data from remnant sites and modelling based on soil and geological associations and ecological interpretations of current plant distributions. This work confirms and indeed was largely influenced by earlier work (Benson & Howell 1990, Benson 1992) that included similar reliance on remnant vegetation, but interpreted this with more reference to historical evidence. Cumberland Plain Woodland in western Sydney is now confined to less than 10% of its original extent with most remaining as small remnants. Conservation areas include Scheyville National Park and Mulgoa Nature Reserve.

Mount Annan Conservation Woodland site

Remnants of Cumberland Plain Woodland occur in Mount Annan Botanic Garden at Campbelltown, where they are being managed as conservation areas for the local flora and dependent fauna. Prior to its acquisition for the botanic garden in 1984 this land was part of a rural holding taken up by settlers in the early 1800s. Its past management has been patchy and has included grazing, partial clearing, cultivation and pasture improvement. The woodland remnants appear to have been least disturbed. Grazing probably stopped a year or two before the botanic garden opened in 1988.

Since 1988 we have been monitoring changes in the vegetation in one of these remnants, the Woodland Conservation Area. This particular remnant was set aside for conservation in Mount Annan Botanic Garden in 1988 and contains about 10 ha of Cumberland Plain Woodland vegetation. It has large trees of *Eucalyptus moluccana, Eucalyptus tereticornis* and *Eucalyptus crebra*, 26 native grass species in the ground cover including *Themeda australis* and species of *Aristida* and *Chloris*, and shrubs mainly of *Bursaria spinosa*. Ground cover includes both native and exotic species. In 1988 the groundcover was predominantly grassy and parts appeared to have been slashed in the previous year.

How similar is this current vegetation to what would have been the original pre–settlement vegetation of the site? This paper will discuss how difficult this is to answer and the implications for conservation management.

Documentation of Cumberland Plain vegetation — then and now

Evidence from historical documentation is often used to interpret current vegetation issues, both broadly, e.g. the general nature of NSW pre–settlement vegetation (e.g. Benson & Redpath 1997), and locally, e.g. extent of mangroves along the Parramatta River in the 19th century (McLoughlin 2000). However it is generally not appreciated how limited is our window onto the 19th century landscape. It was not until 1900 that Joseph Maiden, Director of the then Sydney Botanic Gardens, organised the first systematic collecting of NSW plants emphasising geographical distribution. These collections of local plants were the first to be retained officially within NSW, in the National Herbarium of New South Wales, and it is only from this time that the state's botanical records begin to become comprehensive. Sources of information on plant distribution patterns in NSW prior to this are limited to the specimens and notes of botanical collectors, including well known botanists Joseph Banks, George Caley and Robert Brown, who were primarily interested in describing individual species and who sent their specimens back to Europe. Additional sources of information are the records of explorers, often with strong botanical interests, who were searching for new country. Thomas Mitchell and Allan Cunningham stand out. Their writings provide descriptions of the landscape with insights into some of the ecological processes affecting vegetation, e.g. effects of soil, flooding, fire and aboriginal impacts. Once an area had begun to be settled attention turned to the development of the land rather than its natural features.

The most convincing descriptions of the Sydney landscape are those made during the first 30 years of settlement (1788–1820), particularly the First Fleet diaries of Watkin Tench, William Bradley and John White (see Benson & Howell 1990, for examples). For the next 100 years, with the exception of descriptions of particular places (e.g. Louisa Meredith describing Homebush, William Woolls describing the Native Vineyard at Cobbitty), there are very few detailed descriptions of the natural landscape of the Sydney area. It was not until the 1920s–40s that descriptive ecology and vegetation became a serious subject for university studies e.g. the studies at Mount Wilson (e.g. Brough, McLuckie & Petrie 1924), Bulli (e.g. Davis 1936) and Ilma Pidgeon's work on Sydney vegetation (e.g. Pidgeon 1937). Of course by that time much of the pre–settlement vegetation had already been severely changed or swept away.

Woodland structure and appearance in early colonial times

Our view of the vegetation structure of pre–settlement Cumberland Plain Woodland (as described in Benson & Howell 1990) is based on accounts such as the following.

In April 1788 Governor Phillip exploring country to the west of Parramatta and typical of the Cumberland Plain landscape reported, 'The country through which they [Phillip] travelled was singularly fine, level, or rising in small hills of a very pleasing and picturesque appearance. The soil excellent, except in a few small spots

where it was stony. The trees growing at a distance of from 20 to 40 feet [6–12 m] from each other, and in general entirely free from brushwood, which was confined to the stony and barren spots.' (Phillip 1789).

In 1826 James Atkinson in his authoritative *Account of the state of agriculture & grazing in New South Wales* wrote, 'In the county of Cumberland, one immense tract of forest land extends, with little interruption, from below Windsor, on the Hawkesbury, to Appin, a distance of 50 miles; large portions of this are cleared and under cultivation, and of the remainder that is still in a state of nature, a great part is capable of much improvement. The whole of this tract, and indeed all the forest in this county, was thick forest land, covered with very heavy timber, chiefly iron and stringy bark, box, blue and other gums, and mahogany.' He had previously noted, 'It is, however, always to be understood that forest land means land more or less furnished with timber trees, and invariably covered with grass underneath, and destitute of underwood.'

Traveller Peter Cunningham wrote similarly in 1827, 'Beyond this commences a fine timbered country, perfectly clear of brush, through which you might, generally speaking, drive a gig in all directions, without any impediment in the shape of rocks, scrubs or close forest. This description of country commences beyond Parramatta on one hand, and Liverpool on the other; stretching in length south easterly obliquely towards the sea, about forty miles and varying in breadth nearly twenty.' (Cunningham 1827).

These accounts indicate a wooded community with a grassy groundcover. There is pictorial evidence confirming this. For example a painting of the Government Hut at the Cowpastures in 1804 shows the trunks of the gum trees and the generally open nature of the understorey (Figure 11 in Benson & Howell 1990).

From a range of sources it is clear that the trees were the box, ironbark and gums (*Eucalyptus moluccana, E. crebra* and *E. tereticornis)* of today's remnants; for example James Atkinson (1826) writes of, 'Box, this tree abounds in all the forest lands in the county of Cumberland and cow pasture district' and of 'Iron Bark, this tree abounds in the county of Cumberland and many other parts of the Colony.' Robert Brown reported *Themeda australis* near 'Badgerys Farm' close to Richmond.

Woodland structure and appearance in present times

The canopy in the Woodland Conservation Area at Mount Annan includes large *Eucalyptus* trees of the species mentioned above, up to 25 m in height. These have been assumed to indicate that the site has always been a remnant of the original woodland, and that the immediate ground has not been cultivated or disturbed except by stock grazing. In 1988 with its mature eucalypt canopy and grassy groundcover the site had the appropriate structure for a woodland remnant compared with Phillip's descriptions above — large trees 20 to 40 feet apart with an open ground layer (Figure 1). During the period of study 1988–2002, however, details of the structural appearance of the remnant changed. *Bursaria* shrubs grew very vigorously to form some dense thickets, but spread only slowly laterally. Small eucalypt saplings already present in 1988 grew in size forming local cohorts of even-aged trees. Fires also produced short periods of opening up of the understorey. From 1988 until the mid 1990s there appeared to be a period of gradual death of many of the *Eucalyptus crebra* ironbark trees, probably as a result of previous stress during the major drought of the early 1980s.

Fig. 1. View of the same location in Woodland Conservation Area at Mount Annan Botanic Garden in December 1988 (above) and February 2002 (below) showing change in *Bursaria* cover in particular.

Structure in Cumberland Plain Woodland is clearly subject to change over relatively short periods of time. Fire may remove ground layer and shrub foliage and create bare ground that favours seedling recruitment after rain. These impacts on structure may be relatively short-lived if good rain after fire promotes resprouting of herbs, grasses and shrubs, particularly *Bursaria,* or may be extended by frequent fires or post-fire drought. Grazing by domestic stock also affects structure of the ground layer, and we would expect such impacts to be different from those of native fauna. Drought may affect all components in different ways, but effects on trees are likely to be the most far-reaching. Given the structure found in Cumberland Plain remnants today, and the range recorded within one stand, it is an oversimplification to try to come up with an idealised model based on the historical accounts and say that the pre–settlement Cumberland Plain Woodland all looked like this.

Current woodland floristic composition at Mount Annan

During the period 1988–2002, nearly 190 plant species have been recorded in the Woodland Conservation Area, including species present in many remnants in western Sydney. The floristic list for Mount Annan includes 126 native and 62 exotic species as currently regarded (Table 1). However, 500–600 native species occur in Cumberland Plain Woodland across western Sydney, so there is variation in composition between remnants, mostly in the ground layer. At Mount Annan there are only three canopy trees (the fourth tree species occurs as an occasional seedling), and of the dozen shrubs only two occur in any abundance, *Bursaria spinosa* and the exotic *Olea europea* subsp. *africana*. The vast majority of both natives and exotics are groundlayer species.

Table 1. Native and exotic species recorded in Mount Annan Woodland Conservation Area 1988–2002 showing earliest recording (natives only, excluding grasses and graminoids) of CPWL species in Sydney area.

PJ=Port Jackson, BM=Blue Mountains, *RBr*=Robert Brown

Frequency based on 1988–96 plot data, and other observations:
C=75–100%; F=50–75%; O=25–50% R=0–25% *=weed #=problem weed

Species	Family	Historical record location/collector	Frequency 1988–96
Trees			
Brachychiton populneus	Sterculiaceae	*J. Atkinson*	R
Eucalyptus crebra	Myrtaceae	Smithfield, *Woolls*	F
Eucalyptus moluccana	Myrtaceae	Parramatta, *Woolls*	C
Eucalyptus tereticornis	Myrtaceae	PJ, *Woolls*	C
Shrubs			
Acacia falcata	Fabaceae		R
Acacia implexa	Fabaceae	PJ, *RBr*	R
Acacia parramattensis	Fabaceae	PJ-BM, *RBr*	R
Bursaria spinosa	Pittosporaceae		C
Cassinia quinquefaria	Asteraceae	BM, *Caley*	R
Cassinia uncata	Asteraceae		R
Clerodendrum tomentosum	Verbenaceae		R
Daviesia ulicifolia	Fabaceae	PJ, *RBr*	R

Species	Family	Historical record location/collector	Frequency 1988–96
Dodonaea viscosa subsp. *cuneata*	Sapindaceae	PJ, *RBr*	R
Exocarpos cupressiformis	Santalaceae	PJ, *RBr*	R
Indigofera australis	Fabaceae	PJ-BM, *RBr*	R
Myoporum montanum	Myoporaceae	Cowpastures, *RBr*	R
Olea europaea subsp. *africana**	Oleaceae		F#
Ozothamnus diosmifolius	Asteraceae	PJ-BM, *RBr*	R
Vines and climbers			
*Araujia sericifera**	Asclepiadaceae		R
Clematis aristata	Ranunculaceae		R
Convolvulus erubescens	Convolvulaceae	PJ-BM, *RBr*	R
Parsonsia straminea	Apocynaceae		R
Groundlayer			
Ferns			
Asplenium flabellifolium	Aspleniaceae	PJ-BM, *RBr*	R
Cheilanthes distans	Sinopteridaceae		R
Cheilanthes sieberi	Sinopteridaceae	PJ, *RBr*	F
Pellaea falcata	Sinopteridaceae	PJ-BM, *RBr*	R
Herbs			
Asteraceae – Daisy family			
Brachycome angustifolia	Asteraceae	Goulburn, *Cunningham*	R
Calotis lappulacea	Asteraceae	PJ-BM, *RBr*	R
*Carthamus lanatus**	Asteraceae		R
*Cirsium vulgare**	Asteraceae		O
*Conyza albida**	Asteraceae		R
Cotula australis	Asteraceae	PJ-BM, *RBr*	R
Cymbonotus lawsonianus	Asteraceae	PJ, *RBr*	R
Euchiton gymnocephalus	Asteraceae		R
Euchiton sp. *E (=aff. argentifolium)*	Asteraceae		R
*Facelis retusa**	Asteraceae		R
*Gamochaeta americana**	Asteraceae		R
*Hypochaeris radicata**	Asteraceae		F
Hypochoeris microcephala var. *albiflora**	Asteraceae		R
Lagenifera gracilis	Asteraceae	PJ-BM, *RBr*	R
*Leontodon taraxicoides**	Asteraceae		R
Rhodanthe anthemoides	Asteraceae		R
*Senecio madagascariensis**	Asteraceae		C
Senecio quadridentatus	Asteraceae	PJ-BM, *Sieber*	R
Solenogyne bellioides	Asteraceae	PJ, *RBr*	R
Solenogyne dominii	Asteraceae		R
*Soliva sessilis**	Asteraceae		R
Sonchus oleraceus	Asteraceae	PJ, *RBr*	F
*Taraxicum officinale**	Asteraceae		R
Vernonia cinerea	Asteraceae	PJ-BM, *Woolls*	R
Vittadinia cuneata var. *cuneata*	Asteraceae	PJ, *RBr*	R
Fabaceae – Pea family			
Desmodium brachypodum	Fabaceae	PJ-BM, *RBr*	R
Desmodium varians	Fabaceae	PJ, *Banks, RBr*	F

Species	Family	Historical record location/collector	Frequency 1988–96
Glycine tabacina	Fabaceae	PJ-BM, *RBr*	C
Hardenbergia violacea	Fabaceae	PJ-BM, *RBr*	R
Lotus australis	Fabaceae	Hunter River, *RBr*	R
*Medicago lupulina**	Fabaceae		R
*Trifolium campestre**	Fabaceae		R
*Trifolium glomeratum**	Fabaceae		R
*Trifolium striatum**	Fabaceae		O
Zornia dictyocarpa	Fabaceae	PJ, *RBr*	R
Other Dicot Herbs			
Ajuga australis	Lamiaceae	PJ-BM, *RBr*	R
Alternanthera sp. *A*	Amaranthaceae		R
*Anagallis arvensis**	Primulaceae		F
Asperula conferta	Rubiaceae	Parramatta, *Woolls*	C
Atriplex semibaccata	Chenopodiaceae	PJ, *RBr*	R
Brunoniella australis	Acanthaceae	PJ, *RBr*	C
*Centaurium tenuiflorum**	Gentianaceae		R
Chamaesyce drummondii	Euphorbiaceae		R
*Ciclospermum leptophyllum**	Apiaceae		O
Crassula sieberiana	Aizoaceae		R
Daucus glochidiatus	Apiaceae	PJ-BM, *Sieber,Cunningham*	R
*Datura stramonium**	Solanaceae		R
Dichondra repens	Convolvulaceae	Parramatta, *RBr*	C
*Echium plantagineum**	Boraginaceae		R
Einadia hastata	Chenopodiaceae	PJ, *RBr*	O
Einadia nutans subsp. *linifolia*	Chenopodiaceae		O
Eremophila debilis	Myoporaceae	PJ-BM, *RBr*	R
Erodium crinitum	Geraniaceae		R
Galium propinquum	Rubiaceae	PJ-BM, *RBr*	R
Geranium solanderi	Geraniaceae	PJ, *RBr*	C
Goodenia hederacea	Goodeniaceae	PJ-BM, *RBr*	R
*Heliotropium amplexicaule**	Boraginaceae		R
Hypericum gramineum	Hypericaceae	PJ, *RBr*	R
*Hypericum perforatum**	Hypericaceae		R
*Lepidium africanum**	Brassicaceae		O
*Lepidium bonariense**	Brassicaceae		R
*Linum trigynum**	Linaceae		R
Lythrum hyssopifolia	Lythraceae	PJ, *Herb, Hooker*	R
Mentha satureioides	Lamiaceae	PJ-BM, *RBr*	O
*Modiola caroliniana**	Malvaceae		R
Opercularia varia	Rubiaceae	PJ, *RBr*	R
Oxalis perennans	Oxalidaceae	PJ, *Beckler*	C
*Paronychia brasiliana**	Caryophyllaceae		R
*Petrorhagia nanteuilii**	Caryophyllaceae		R
Phyllanthus virgatus	Euphorbiaceae		R
Pimelea spicata	Thymelaeaceae	PJ & neighbouring dist. *RBr*	R
Plantago gaudichaudii	Plantaginaceae		O

Species	Family	Historical record location/collector	Frequency 1988–96
*Plantago lanceolata**	Plantaginaceae		C
*Plantago myosuros**	Plantaginaceae		R
Plectranthus parviflorus	Lamiaceae	PJ-BM, *RBr*	R
*Polycarpon tetraphyllum**	Caryophyllaceae		R
Polygala japonica	Polygalaceae	Botany Bay, *RBr*	R
Poranthera microphylla	Euphorbiaceae	PJ-BM, *RBr*	R
Ranunculus lappaceus	Ranunculaceae	PJ & interior, *RBr*	R
Ranunculus sessiliflorus	Ranunculaceae		R
*Richardia stellaris**	Rubiaceae		F
*Rosa rubiginosa**	Rosaceae		R
Rubus parvifolius	Rosaceae		R
Rumex brownii	Polygonaceae	PJ, *RBr*	R
Scutellaria humilis	Lamiaceae	PJ, *RBr*	R
*Sherardia arvensis**	Rubiaceae		R
Sida corrugata	Malvaceae	Hawkesbury River, *RBr*	F
*Sida rhombifolia**	Malvaceae		F
Silene gallica var. *gallica**	Caryophyllaceae		R
*Solanum chenopodioides**	Solanaceae		R
Solanum cinereum	Solanaceae	Grose River, *RBr*	R
Solanum prinophyllum	Solanaceae	PJ, *RBr*	R
*Stachys arvensis**	Lamiaceae		R
Stackhousia viminea	Stackhousiaceae	PJ, *RBr*	R
*Stellaria media**	Caryophyllaceae		R
*Verbascum virgatum**	Scrophulariaceae		R
*Verbena bonariensis**	Verbenaceae		R
*Verbena litoralis**	Verbenaceae		R
*Verbena officinalis**	Verbenaceae		R
*Verbena rigida**	Verbenaceae		R
Veronica plebeia	Scrophulaceae	PJ-BM, *RBr*	O
Wahlenbergia communis	Campanulaceae		R
Wahlenbergia gracilis	Campanulaceae	PJ-BM, *RBr*	O
Wahlenbergia stricta	Campanulaceae		R
Groundlayer – Grasses			
Agrostis avenacea	Poaceae		R
Aristida ramosa	Poaceae		C
Aristida vagans	Poaceae		R
Austrodanthonia bipartita	Poaceae		R
Austrodanthonia pilosa	Poaceae		C
Austrodanthonia racemosa var. *obtusata*	Poaceae		R
Austrodanthonia tenuior	Poaceae		R
Bothriochloa macra	Poaceae		O
*Briza maxima**	Poaceae		R
*Briza minor**	Poaceae		R
*Briza subaristata**	Poaceae		R
*Bromus molliformis**	Poaceae		O
*Bromus unioloides**	Poaceae		R

Species	Family	Historical record location/collector	Frequency 1988–96
Chloris truncata	Poaceae		O
Chloris ventricosa	Poaceae		C
Cymbopogon refractus	Poaceae		R
*Cynodon dactylon**	Poaceae		O
Dicanthium sericeum	Poaceae		R
Dichelachne micrantha	Poaceae		C
Echinopogon ovatus	Poaceae		O
Elymus scaber	Poaceae		R
Eragrostis molybdea	Poaceae		R
Eragrostis trachycarpa	Poaceae		R
Eriochloa pseudoacrotricha	Poaceae		R
*Eriochloa crus-galli**	Poaceae		R
*Lolium perenne**	Poaceae		R
Microlaena stipoides	Poaceae		C
*Nassella neesiana**	Poaceae		R#
Oplismenus imbecillis	Poaceae		R
Panicum effusum	Poaceae		R
Paspalidium distans	Poaceae		R
*Paspalum dilatatum**	Poaceae		C
Poa labillardieri	Poaceae		F
*Setaria geniculata**	Poaceae		O
Sorghum leiocladum	Poaceae		R
*Sporobolus africanus**	Poaceae		R
Sporobolus creber	Poaceae		F
Themeda australis	Poaceae		F
*Vulpia bromoides**	Poaceae		O
Groundlayer – Graminoids			
Arthropodium milleflorum	Anthericaceae		R
Caesia parviflora var. *vittata*	Anthericaceae		R
Carex breviculmis	Cyperaceae		R
Carex inversa	Cyperaceae		C
*Cyperus eragrostis**	Cyperaceae		R
Cyperus gracilis	Cyperaceae		O
Dianella longifolia	Phormiaceae		R
Eleocharis cylindrostachys	Cyperaceae		R
Fimbristylis dichotoma	Cyperaceae		R
Hypoxis hygrometrica	Hypoxidaceae		R
Juncus prismatocarpus	Juncaceae		R
Juncus subsecundus	Juncaceae		R
Lomandra filiformis subsp. *filiformis*	Lomandraceae		C
Lomandra multiflora	Lomandraceae		R
Pterostylis curta	Orchidaceae		R
*Romulea rosea**	Iridaceae		R
Scleria mackaviensis	Cyperaceae		R
Sisyrinchium sp. *A (sensu micranthum)**	Iridaceae		R
Tricoryne elatior	Anthericaceae		O

Typical sandstone woodland has a much higher proportion of native shrub species, as shown by the comparison in Table 2. Early botanists such as Allan Cunningham report that the floristic composition of western Sydney, principally the Cumberland Plain Woodland, was quite different from that of the typical Sydney coastal sandstone flora with its conspicuous shrubby component and its predominance of families Fabaceae, Proteaceae and Rutaceae.

Table 2. Number of native and exotic species by life-form in Cumberland Plain Woodland at Mount Annan, and comparison with woodland on sandstone; A. 12 plots, 0.3 ha, Woodland Conservation Area, Mount Annan Botanic Garden, B. 2 sites, 0.2 ha, Ku-ring-gai Chase NP.

Number of species in Woodland Conservation Area, Mount Annan Botanic Garden (10 ha)					
	Trees	**Shrubs**	**Groundplants**	**Climbers**	**Total**
Natives	4	13	106	3	126
Exotics		1	60	1	62
Number of native species by life-form					
Woodland on shale[A]	2	2	78	-	82
Woodland on sandstone[B]	9	66	68	5	148

Current species abundance (frequency at recording plots 1988–96 and in the woodland generally) is also shown (Table 1). The only common shrub is *Bursaria spinosa* while the common groundcover species are the natives *Themeda australis, Brunoniella australis, Glycine tabacina, Asperula conferta, Dichondra repens, Geranium solanderi, Oxalis perennans, Aristida ramosa, Austrodanthonia pilosa, Chloris ventricosa, Dichelacne micrantha, Microlaena stipoides, Carex inversa* and *Lomandra filiformis.* Common exotics are *Senecio madagascariensis, Plantago lanceolata* and *Paspalum dilatatum.*

Were these the species in the woodland here in 1788?

Although Banks and Solander made the first plant collections in the Sydney area in 1770, their collections were from a limited area and remained undescribed for many years. Robert Brown's 1802–05 collections however were used in contemporary publications and many of his records are included in Bentham's *Flora Australiensis*. Using this and Brown's recently available *Diary* (Vallance et al. 2001) we have been able to confirm that most of our Cumberland Plain Woodland species at Mount Annan were reported in the Sydney area in the early years of the 19th century (Table 1). We found that 62 of 84 of the woodland's dicotyledonous species are known to have been collected by early colonial botanists, that is, 70% of the dicot species excluding some problematic groups such as *Gnaphalium* and *Vittadinia* where old names are difficult to correlate with collections. These early collections include 50 by Brown (annotated as either 'Port Jackson' or 'Port Jackson to the Blue Mountains'), with an additional two of the species being collected by George Caley and one by Joseph Banks (in 1770). A similar result appears to apply to the monocotyledons but our unfamiliarity with grass synonymy makes tracing old names here difficult. Given

that Brown did not travel much beyond the Hawkesbury and Nepean Rivers it is evident that the majority of our woodland species were undoubtedly part of the Sydney area flora in 1802–05 and are highly likely to have been present in the pre–settlement Cumberland Plain Woodland of western Sydney.

Brown also recognised that the native landscape was changing as a result of European settlement and that non-native species were being introduced into the farmed and settled areas, and along roads. Of his list of 29 weeds recorded for the Sydney area (1802–05) (see Richard Groves' paper, page 623) *Cynodon dactylon, Silene gallica, Stachys arvensis, Lolium perenne, Anagallis arvensis* and *Briza minor* occur in the Mount Annan Woodland. Interestingly 19th century botanists regarded *Sonchus oleraceus* also now occurring in our woodland, as a cosmopolitan and native species — Allan Cunningham records it in a list of native species on the Cudgegong River in 1822 in box woodland with *Themeda australis*, country similar ecologically to Cumberland Plain Woodland. In view of this evidence we include *Sonchus* as a native and *Cynodon* as an exotic in our tables. As a final note we record that *Ludwigia peploides* subsp. *montevidensis,* now found in floodplain wetlands along the Hawkesbury River is clearly native and not an introduced species (cf. Dalby 2002). Brown records it 'at the margin of Yellowmundy's Lagoon', now Yarramundi Lagoon near Richmond in his diary on 14th September 1804 (Vallance et al. 2001).

Assuming that these species were part of the pre–settlement Cumberland Plain Woodland can we get a better idea of the original abundance of species? Brown does not include descriptions of the landscape nor much on the habitats of individual species or their abundance — after all he was a taxonomist focussed solely on listing and describing the plants, appropriate for a first encounter with a largely unknown flora. However from other writers particularly botanist/explorer Allan Cunningham, we can get snippets of information.

Allan Cunningham's Journal (quoted in Lee 1925), '22/10/1817 At the invitation of a friend I went out to his farm near Liverpool, … *Daviesia corymbosa*, very frequent in the forest land, in flower. … In the forest land I gathered seeds of a *Helichrysum*, leaves linear, flowers white. Like other farms in the neighbourhood it is overrun with the *Bursaria spinosa*, now in fruit.

19/10/1819 … To the southward of Liverpool the country is an open forest-land of common Eucalypti, in which *Exocarpus cupressiformis*, and the papilionaceaous tree *Jacksonia scoparia*, at this period laden with yellow flowers, are very conspicuous. *Pimelea spicata* and *P. glauca* of Mr. Brown; a small *Daviesia* with cordate leaves *(D. squarrosa*, Smith); with a *Helichrysum*, allied to *H. papillosum* and prevalent in this description of country. … In situations on the roadside, more or less subject to inundation, a delicate, tufted small *Lobelia (L. inundata)* is in flower, and *Ruellia australis* [*Brunoniella australis*] is common in grassy dry spots, decorating our path throughout this day's route.'

Although fragmentary, these notes indicate some of current woodland species that were relatively conspicuous in the open-forest country in the Liverpool area early in the 19th century. Some species are common in our woodland today, e.g. *Bursaria spinosa* and *Brunonella australis*, others also occur in our woodland but are rare *Pimelea spicata, Exocarpos cupressiformis* and *Helichrysum*. *Pimelea glauca* has been found in another remnant about 1 km away.

How much of the presettlement flora has been lost?

Settlement of the Cumberland Plain took place from the early 1800s as domestic stock were moved in. During the next hundred years grazing was widespread while clearing for cultivation was extensive in many areas. In the 20th century urban development expanded into many areas. Our site at Mount Annan is probably typical of many Cumberland Plain remnants. Over the past 200 years it is likely to have suffered from a range of impacts: grazing by domestic stock (sheep, cattle, horses) and rabbits, partial clearing, cultivation for pasture improvement, deliberate introduction of pasture, accidental introduction of weeds, and altered fire regimes (though not necessarily all parts of the area were impacted to the same degree).

The list of native plant species still occurring in western Sydney in the 1990s has over 1200 species (James et al. 1999), though this study includes species on the sandstone margin lands. There are probably about 500–600 species that occur on the shale areas and associated alluvial areas that support Cumberland Plain Woodland (Benson & McDougall 1991). This is still a considerably rich flora for an area that has undergone a considerable amount of environmental disturbance. Of the 1200 species however about 700 species are listed as regionally vulnerable in western Sydney. Many are now rare. For example for western Sydney, 502 species were recorded from 5 or fewer sites.

Given the extent of disturbance one would expect that many native species would have been lost from the woodland flora as a whole. However the only western Sydney species to be nationally listed as extinct in recent years is *Hypsela sessiliflora* which was probably a component of River-flat Forest rather than Cumberland Plain Woodland. Interestingly one of the few collections of *Hypsela* was by Ferdinand *Bauer* who was collecting for Brown. *Hypsela* was rediscovered recently near Penrith.

Table 3. Species recorded in Camden/Campbelltown in the 19th Century, most likely as part of Cumberland Plain Woodland, but now regarded as Extinct or Rare.

Extinct species

Thesium australe: recorded Cow Pastures 1803, mentioned by Cunningham at Emu Plains (7/9/1817) and Parramatta (6/9/1818) now extinct in western Sydney (James et al. 1999)

Swainsona monticola: recorded Cow Pastures 1802, Georges River 1910, Camden 1965 now extinct in western Sydney (James et al. 1999).

Rare species

Pimelea spicata: recorded Liverpool 1819

Pimelea glauca: recorded Liverpool 1819, Camden 1990s

Myoporum montanum: recorded Cow Pastures, R. Brown (21/10/1803)

Velleia paradoxa: recorded Campbelltown 1893 but not collected in Sydney area since 1945 (Benson & McDougall 1997

Vittadinia tenuissima: recorded Mount Hunter, R. Brown (23/10/1803)

Our list of species recorded from the Camden/Campbelltown area in the 19th century and now regarded as Extinct in western Sydney (Table 3) is very short, two species *Thesium australe* and *Swainsona monticola* (though bear in mind that there is very little documentation from the 19th century). Additionally about 150 regionally vulnerable

species have been recently recorded in Cumberland Plain Woodland in the Camden and Campbelltown local government areas (James et al. 1999). A number of these occur in our study area in the Woodland Conservation Area, including *Pimelea spicata, Rhodanthe anthemoides, Sorghum leiocladum, Calotis lappulacea, Vernonia cinerea* and *Ranunculus lappaceus*.

Were these species rare in the presettlement vegetation? *Thesium* appears to have been relatively common. Cunningham (in the limited documentation we have access to) refers to *Thesium* in several places in western Sydney. He also refers to *Pimelea glauca* and *Pimelea spicata* with apparent familiarity suggesting these species may have once been more common in Cumberland Plain Woodland. There are no references to *Swainsona monticola* between 1802 and 1965 (after which its only occurrence is destroyed by lawnmowing). *Myoporum montanum* is mainly confined to hilly country around Razorback and may have always been restricted though relatively common in this area (Razorback because of its steeper topography and sandstone bands within the Wianamattta strata has a number of species, particularly dry rainforest species, not found elsewhere in western Sydney).

Given the magnitude of change in western Sydney, intuitively one would think that many species went extinct early after settlement. However, we have not been able to find evidence that many Cumberland Plain Woodland species have completely disappeared. *Thesium* and *Swainsona* are the only clearcut examples. Did many species go extinct before they were ever recorded? In our view Brown's highly regarded collecting record suggests that this is unlikely. Our reading of Brown is that he was a dedicated and methodical collector, working with the intention of recording all of the plants that he possibly could. As soon as he had collected a new species and made notes on it, he could dismiss it from his mind, and turn to the next species. He was not interested in whether species were common or rare, or how they related to the landscape, things that modern ecologists would spend a lot of time sampling. As a result he could move through the district very efficiently, recording all the species. With a collector's eye for detail however he may have surveyed as many different local habitat types as possible, and multiple visits at different seasons would have allowed him to pick up additional species. As a result we are confident he would have recorded a very high percentage of the flora of the areas he visited. In the 1970s, using a similar traditional approach, Royal Botanic Gardens' collector Bob Coveny was able to compile very extensive lists of plant species for Royal National Park from a limited number of trips covering the major habitats of the Park. It was rare to find a species that Bob had not found there.

In addition, although Brown only sampled limited transects through the Cumberland Plain Woodland, the areas appear to have been relatively continuous with few geographic barriers and little natural fragmentation. Creeks provide the main local variation. In contrast, for example, coastal rainforest, where new species are still not infrequently discovered, e.g. *Eidothea hardeniana* in 2000 (Weston & Kooyman 2002), is naturally dissected, occurring as discontinuous, isolated pockets with relatively large distances between them. There are many isolated occurrences of species and many species with low frequency.

Species longevity and mechanisms for persistence

In our view therefore the floristic list as recorded by James et al. (1999) probably reflects the original presettlement flora though the local distribution and frequencies of many species have changed as a result of the fragmentation of woodland remnants that recent development and clearing has produced. Given the types of disturbance over the last 200 years, are there any characteristics of the flora that may have helped species to survive better than we may have expected?

Estimated lifespans

General observations on the canopy eucalypts suggest they are relatively long-lived and the presence of large individuals generally indicates minimal disturbance to the immediate surrounding soil surface. Trying to establish lifespan ages for groundlayer species is more difficult. Having observed the Cumberland Plain Woodland flora at Mount Annan for almost 20 years we have tabulated our views (Table 4) on the lifespan classes for the native and exotic species there. About 25% of the native species are very long-lived perennials (mainly trees) or indefinite perenials (e.g. rhizomatous sedges). We think that such species may survive for centuries. A further 25% we regard as long perennial (5–50 years), though we may be being conservative and these may be longer-lived than we think. Many of these species have thick fleshy roots and die back above ground during dry seasons, responding quickly when conditions improve. About 50% are annuals and short perennials though many of these may be able to live up to 5 years. Most of the grasses are in this group. In contrast about 80% of the exotic species fall into the short-lived class. (Note that differences in total species number between Table 1 and Tables 4 and 5 reflect lack of observations of uncommon species.)

Table 4. Estimated lifespan classes for native and exotic species in Cumberland Plain Woodland at Mount Annan

	Annual 1 year	**Biennial 2 years**	**Short perennial 1–5 years**	**Long perennial 5–20 years**	**Very long perennial 50–200 yrs**	**Indefinite perennial indeterminate yrs**
Native species 104	7		44	27	5	20
Exotic species 59	26	7	14	6	1	5

Resprouting after drought and fire

Table 5 shows that about 25% of the native flora is capable of local vegetative expansion, that is that under suitable conditions they are able to expand their local populations by spreading by rhizomes, root suckers, etc. This allows quick recovery after dry periods, intensive grazing, fire or other physical above ground disturbances. Few exotic species have this capability though the few that do include the more successful weeds e.g. *Hypericum perforatum, Nassella neesiana*.

Table 5. Number of native and exotic species capable of local vegetative expansion

	Capable of local vegetative expansion	Not capable
Native species 104	23	81
Exotic species 59	4	55

Fire is a natural component of the ecology of Cumberland Plain Woodland. Fire responses observed for native and exotic species at Mount Annan are shown in Table 6. Nearly half of the native species are known to resprout, the large number of unknowns being due to the fact that only a small part of the woodland has been burnt during our studies. It is suspected that the majority of these 'unknown' species will also be able to resprout after fire. One native species, *Dodonaea viscosa* subsp. *cuneata*, and one weed, *Araujia sericifera* showed both responses, apparently depending on fire intensity and age of plant.

Table 6. Fire responses observed in Cumberland Plain Woodland at Mount Annan for native and exotic species.

	Resprout	Killed	Not known*
Native species 126	63	3	61
Exotic species 62	12	3	48

One of the main attributes of many of these Cumberland Plain Woodland species is long term persistence at a site. Cumberland Plain Woodland is now restricted to small remnants scattered across western Sydney. Most species-rich remnants occur at sites where there is still a natural old soil surface that has not been destroyed by ploughing or filling. The occurrence of a few old trees generally supports the view that these are relict sites that have not been ploughed. Many Cumberland Plain Woodland species are long-lived, and capable of withstanding harsh conditions, particularly drought. The frequency of fleshy storage roots in the Cumberland Plain Woodland flora, (and we would think it is a more frequent character than in the nearby Sandstone flora), suggests that drought survivorship has been a most important factor in the longterm survival of the flora. Indeed many of the Cumberland Plain Woodland species are able to survive under a much lower rainfall than the 750 mm pa of the Campbelltown area. Some of the frequent Cumberland Plain Woodland species including *Aristida ramosa, Brunoniella australis, Dichondra repens, Geranium solanderi, Tricoryne elatior* and *Sida corrugata*, also grow in woodland with a rainfall of 350–500 mm in the Forbes–Lake Cargelligo area, for example (Sivertsen & Metcalfe 1995).

Plant responses to drought that allow dying back and resprouting, also enable plants to survive fire, especially for long-lived plants species that do not require frequent seedling recruitment. These attributes may explain how the Cumberland Plain Woodland flora has been able to survive the recent european period with its stock and rabbit grazing, though not of course clearing and cultivation of the land itself. It

may also explain how it survived aboriginal burning regimes. Indeed it is tempting to go back further to the period of the last glaciation 18 000 years BP when rainfall was perhaps half of today's. We would suggest that during those conditions the western Sydney landscape had many of the groundlayer Cumberland Plain Woodland species there today, though the eucalypt canopy was probably absent.

Localised versus widespread distributions

A final point. We pointed out above that the pre–settlement distribution of Cumberland Plain Woodland species and individuals across the gently undulating shale landscape was probably more even and homogeneous than perhaps in more naturally isolated communities such as rainforest. Many species are common and frequent in Cumberland Plain Woodland remnants from Windsor to Picton. Many species are now very infrequent, but apart from clustering of dry rainforest on the steeper topography of Razorback Range, there does not appear to be any obvious clustering together of rare species in particular areas or habitats at the regional scale. At the local scale in the Mount Annan woodland we have patches of a number of regionally rare species including *Pimelea spicata, Rhodanthe anthemoides, Sorghum leiocladum* and *Ranunculus lappaceus*.

Apart from a tendency for some species to favour moister sites, it is difficult to understand why these uncommon species stay relatively confined to the small patches they now occupy (we have observed some of these species closely for up to 14 years). Our thinking is that many of these now rare species were widespread and some possibly common through the pre–settlement Cumberland Plain Woodland landscape, but have been lost in most areas due to fragmentation or subtle habitat changes resulting from rural and urban development. For example, some species may have relatively limited dispersal abilities and once lost from a site are unable to recolonise from a distance. Others may have been linked to animal pollinators or seed dispersers no longer present in woodland remnants. Our current research on life cycles of woodland species is aimed at replacing some of these speculations with facts.

Indeed if the pre–settlement Cumberland Plain Woodland flora was distributed relatively evenly, as we suggest, it is likely that Brown and his collecting colleagues would have noted the vast majority of this flora — remember that they walked or rode through many kilometres of Cumberland Plain Woodland between Parramatta and the Grose or the Cowpastures. It appears to us unlikely therefore that there were a lot of Cumberland Plain Woodland species that were made extinct by European settlement, before they were able to be recorded by science.

Conclusions and implications for conservation and management

Implications from historical data

Primary historical documentation on Sydney vegetation pre-1900 is very limited. It consists of records of plant specimens collected for describing species, and generally not collected once the species was known, and the accounts of explorers and travellers, of varying reliability. Much of the information is either mostly generalised or very site specific.

The available data indicates that the pre–settlement Cumberland Plain Woodland was dominated by a tree canopy with an open grassy understorey with some localised shrubby areas. Individual Cumberland Plain Woodland sites still contain these components, though our experience over the last 14 years shows that these structural components may change relatively quickly in response to changes in grazing, fire and disturbance. For management purposes it is pointless to try to achieve a supposed historical ideal appearance — rather, structure will be the result of treatments aimed to maintain species composition, which may mean maintaining both shrubby and grassy areas as well perhaps as some treeless areas.

Similarly, our knowledge of the local distribution and abundance of species in the 19th century is very limited, and will always remains so (we suspect that our memories of the 20th century landscapes will similarly fade). In terms of species abundance at a particular site, depending on the species, patterns have probably changed from pre-1788 abundances, as a result of sifting by past management practices and current ecological conditions. Because of the very limited nature of the historic accounts, it is not clear whether many species have been lost from the original Cumberland Plain Woodland complement (i.e. became extinct before they could be recorded). We suggest that the original collections, substantially by Robert Brown, were relatively comprehensive and that few 'uncollected' species have been lost.

A surprisingly large number of species still survive overall. In our view therefore the floristic lists recorded in the 1990s (James 1997, James et al. 1999) probably reflect the composition of the original pre–settlement flora, though the regional distribution and local frequencies of many species have changed (and there have been a few introductions from western parts of the state with stock movement).

Maintaining long term diversity

Because of its limitations historical documentation is best used to provide ideas and hypotheses, not to justify management decisions. Our primary guide to plant distributions must remain our currently documented patterns, and our guide to managing vegetation must remain the current ecological responses of the species themselves, as evidenced in current research.

Individual Cumberland Plain remnants may contain a substantial number of native species; that these are clearly native to these sites, is supported by the limited historical documentation available. In terms of biodiversity conservation our aims for each remnant should be to ensure the long-term survival of all native species present at a particular site. Depending on the individual reserve, ecological conditions can be changed to favour selected species or groups of species but this should done in a way that ensures total species composition at each site remains in the long term.

Additional species should not be introduced, unless there is evidence that these come from the same original provenance and there is a particular case to reintroduce them (i.e. needed for ecological processes). Generally however such additions are not necessary, could be done at any time in the future, and detract from the task of managing those species that are already present. With our increasing technical ability to explore the genetic variation within species, it is important that as much of the pre–settlement distribution patterns are maintained at this stage.

Exotic weed species are now rapidly changing most Cumberland Plain Woodland remnants and pose a major problem for management. Interestingly native Cumberland Plain Woodland plants may be able to survive drought, fire and periodic grazing but they may be less well equipped to survive periods of shading and may be vulnerable to crowding out by vigorous growing exotic species such as *Olea europea* subsp. *africana* and *Nassella neesiana*.

Maintaining rarer species

While some common species will occur at almost every site, a considerable number of species are now rare and confined to a few sites, some of which are localised to areas of perhaps only a few square metres. Reasons for occurrence at these sites may be due to historical chance such as land subdivisions, cemeteries, road verges rather than these sites providing particular habitat, soil requirements etc. However individual plants may persist for a long time despite past and present conditions that are not necessarily in their favour. Many Cumberland Plain Woodland species have demonstrated considerable long-term persistence through periods of drought, fire and grazing, but are less able to tolerate major soil disturbance and competition from exotic species. Many Cumberland Plain Woodland species may also have limited distance dispersal abilities for propagules, though they may successfully persist at the local scale.

With our present state of knowledge it is difficult to predict which sites will have unusual species, i.e. it is not clear why they occur where they do. Indeed, unless the variability between sites and the value of small remnants are recognised, the main era of species loss from Western Sydney may be about to begin, as the last surviving remnants in many areas are threatened with destruction.

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