Monitoring vegetation change over 30 years: lessons from an urban bushland reserve in Sydney

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***Abstract*:** For the successful long-term management of biodiversity in conservation reserves, science and management need to work together. In 2008 we resampled two transects in a small urban reserve in northern Sydney under long-term conservation management. The transects were established in 1976 and recorded again in 1987 and 1998 (by other workers). We looked at plant species changes by growthforms, family (Fabaceae) and conservation-significance. Over the 30-year period the structure of the understorey has changed markedly, and despite ongoing weeding programs, the frequency of species identified as significant for conservation has continued to decrease. Despite periodic recommendations for ecological burning since 1987, supported by the monitoring data, this has not been attempted. We discuss the lessons for ecology, monitoring and management evident in this long-term monitoring study.

Key words: vegetation monitoring, adaptive management, understorey change, fire impacts

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Introduction

For the long-term management of biodiversity in conservation reserves, both science and management are needed if successful conservation outcomes are to be achieved. An adaptive management program will allow the results and recommendations coming out of scientific monitoring to be acted upon. This study in a small urban bushland reserve over a 30 year period looks at these issues in practice.

The Ludovic Blackwood Memorial Sanctuary (Blackwood) at Beecroft in the northern suburbs of Sydney conserves a 1.2 ha remnant of Blue Gum High Forest (BGHF), which is listed as an Endangered Ecological Community under both the NSW Threatened Species Conservation Act 1995 and the Australian Government Environment Protection and Biodiversity Act. BGHF occurs in high rainfall areas on clay soils derived from the Wianamatta Shale.

The National Trust of Australia (NSW) – who owns and manages Blackwood – engaged the Bradley sisters in the mid 1970s to advise on managing the vegetation of the site, and the Bradleys and the National Trust conducted early trials in handweeding and minimal disturbance approaches to bush regeneration that have since been adapted and widely applied throughout Australia (Bradley 2002).

Previous reports

Blackwood was also the site of a relatively early example of scientific documentation in urban bushland. In January 1977, in response to increased awareness of shrubby urban bushland weeds (particularly *Ligustrum lucidum,* Large-leaved Privet), the National Trust commissioned a report *The Ludovic Blackwood Memorial Sanctuary – description and management* (Buchanan 1977). As well as making general observations on the tall *Eucalyptus* canopy and indicating that some of the groundlayer shale species were regionally rare at that time, Buchanan set up and recorded three 20m x 1m permanently marked transects to measure groundcover vegetation. At the time Blackwood had mown areas, areas of dense *Pittosporum undulatum* (Sweet Pittosporum) and weedy areas. The mowing stopped in the late 1970s. Buchanan's report not only outlined approaches to weed control but also drew attention to the abundant growth of the native shrub *Pittosporum* which formed a dense, 80–100% cover over much of the site, and discussed its role in native plant suppression.

Buchanan had two management objectives, removal of exotic weeds and encouragement of native plant regeneration. She was confident that unless the exotic *Ligustrum lucidum* was weeded out, it would eventually form a dense shrublayer replacing the *Pittosporum*. She also argued that the dense growth of *Pittosporum* was the result of many fire-free years, and that in the event of a fire these would be killed, while other less common shrubs would survive and flourish. She envisaged that, in the absence of fire, the gradually senescing *Pittosporum* might be replaced by either young regrowing *Pittosporum* or other light requiring species from the mowed borders (she did not know which).

In 1987, in a second report, Buchanan (1987) reported that the weeding program was becoming effective; the *Pittosporum* had been reduced and the native plant species richness had increased. However the understorey species characteristic of the shale soils had declined in frequency, probably due to the absence of substantial disturbance necessary for seedling recruitment, while the herbs, grasses and creepers typical of sheltered gully habitats had increased. To create the disturbance necessary for the recruitment of the shale species, Buchanan recommended a program of burning at 10 year intervals. Apart from some very limited pile burns (about 1 m^2) no burning was carried out.

Pittosporum undulatum is a native species in moist vegetation on medium to high nutrient soils in coastal NSW (such as Blue Gum High Forest at Blackwood) (Howell 2003) though it has spread to become a bushland weed in parts of southern Australia, beyond its natural range (Gleadow & Ashton 1981, Gleadow 1982, Blood 2001). The *Pittosporum* plants (native to Blackwood and noted there in the 1960s) probably recruited in the 1950s, a high rainfall period, and probably following cessation of periodic horse or cattle grazing (which would have been a common use of grassy forest blocks in the first half of the 20th century. The irregular mowing of some areas in the 1970s would have maintained a similar low groundcover impact as grazing, allowing forb and grass species to survive in, and adjacent to mowed areas. Clearing of *Pittosporum* between 1977 and 1987 provided the canopy removal impacts of fire but did not provide the bare ground and heat treatments associated with fire. With the physical removal of the shrub canopy in the 1980s, the vine component took over and spread to become the main understorey canopy layer.

In 1998 Stanton remeasured the Buchanan transects. By1998 the abundance, dominance, and smothering habit of the climbers were having a detrimental effect on regeneration of the vegetation, though the removal of *Pittosporum* had been effective in increasing species richness of previously densely shaded area (Stanton 1998). There was no regeneration of *Pittosporum* in areas from which it had been removed.

Stanton (1998) made recommendations including

- the climbers *Pandorea pandorana*, *Clematis aristata*, *Cayratia clematidea* and *Eustrephus latifolius* should be removed from regenerating trees, shrubs, herbs and grasses
- Fire should be used as a management tool
- Fire intensity should be as high as possible
- Only small sections of the reserve should be burnt at one time followed by a one year study of burn sites
- Weed removal should continue throughout the reserve

A decade has passed since Stanton's recommendations, and though weed control continues in Blackwood, there has been no use of fire. Though the initial methodology only enabled basic statistical analysis, the careful recording of marked plots at 10 year intervals by Buchanan and Stanton provided the impetus to re-record them and assess the vegetation changes over a 30 year period.

The 2008 monitoring

We visited Blackwood in February 2008 to re-record Buchanan's Transects 1 and 3. Neither the Bush Management teams nor National Trust management knew of the location of the original transect markers, so we relocated the sites using measuring tape and compass bearings as accurately as we could from Buchanan's original map of the area. The 2008 plots were marked with steel posts. We recorded species presence in each of the 20 1m x1m plots along each transect as Buchanan did, using a 1–4 scale for abundance within each 1m x 1m plot. Although not precisely located on the original lines, the visual evenness of the vegetation in the immediate site indicated that our recordings are likely to provide a valid comparison.

One-off recordings at 10 year intervals are likely to be affected by seasonal conditions. Buchanan's recording was done in November 1976/ January 1977, and January 1987. Stanton recorded in May 1998, following rain after a hot, dry summer. To be close to Buchanan's timing we recorded in February 2008, during an unusually wet summer. At nearby Parramatta 627 mm rainfall was recorded in the previous six months compared with the long term mean of 393 mm (Bureau of Meteorology).

Data on species richness and individual species frequencies were compared with Buchanan's and Stanton's reports; both of which include appendices of raw data.

Table 1. Native plant species richness (species/sq m +/- se) for two transects at Blackwood Sanctuary Beecroft, 1976–2008.

Transect	1976/77	1987	1998	2008
1	5.1 +/- 0.74	9.5 +/- 1.15	10.2 +/- 0.61	7.5 +/- 0.46
3	9.3 +/- 0.53	10.8 +/- 0.58	10.5 +/- 0.91	10.8 +/- 0.43

Results

Native Species richness per quadrat

Buchanan (1987) reported that between 1977 and 1987 native plant species richness (species/m^2) improved 'dramatically' at Transect 1 and 'increased' at Transect 3 due to an increase in sheltered gully species rather than significant shale species. Levels remained similar in 1998, but in 2008 there was a decrease at Transect 1, though little change at Transect 3. Species richness in 2008 was higher than in 1976 (Table 1). Such results suggest there is little ongoing change in the vegetation. However species richness measures are of limited use in looking at long-term changes, as new species appearances may be counterbalanced by existing ones disappearing; leaving measures with no nett change, though the vegetation dynamics may have changed considerably.

Growthform group changes over time

There have been 56 native species and more than 12 exotics recorded from the two transects over the four recording dates, about 40% of the 139 native species recorded for the whole reserve since 1974. We grouped species by growth-form into shrubs, vines, forbs and grasses/graminoids as used by Buchanan and Stanton. Over the 30 year period the major trend has been an increase in frequency of vine species, with the mean frequency for the 7 species increasing from 10% (2/20) to nearly 60% (12/20) (Figure 1). Fern frequency also rose, particularly in the last 10 years. The mean frequency of grasses, graminoids and groundcover forbs increased in the first decade, presumably in response to the light provided by the removal of the *Pittosporum*, but decreased in the last decade. In 2008 grasses and graminoids were still higher

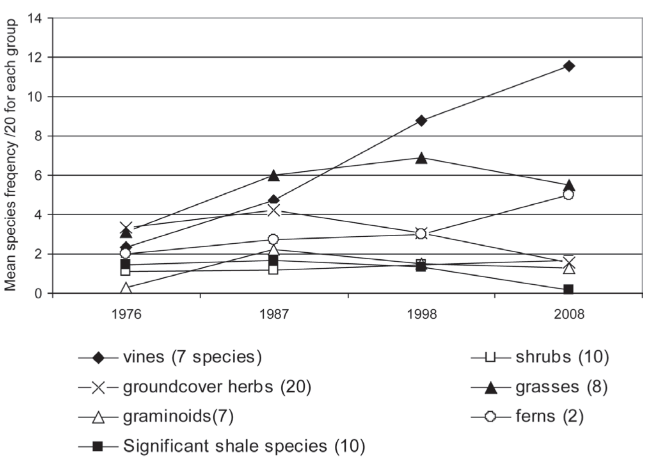

Fig. 1. Mean species frequency for six understorey vegetation growth form groups and the group of conservation-significant shale species at Blackwood over a 30 year period (1976–2008) showing relative increase in importance of vines.

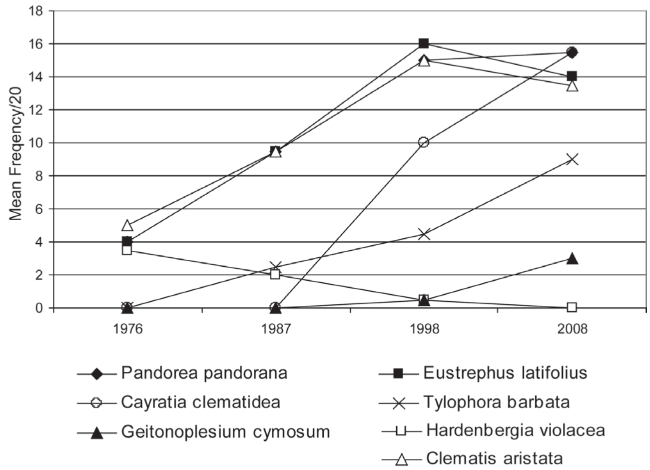

Fig. 2. Mean species frequency for individual vine species at Blackwood (1976–2008) showing increase in most species except *Hardenbergia*.

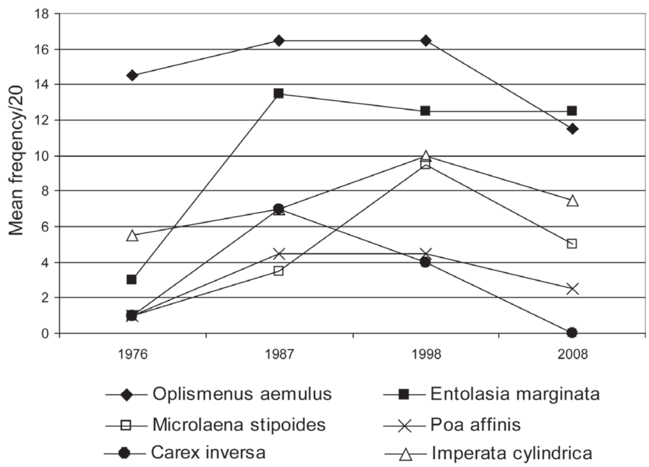

Fig. 3. Mean species frequency for individual monocot species (mostly grasses) at Blackwood (1976–2008) showing initial increase and subsequent decrease for most species.

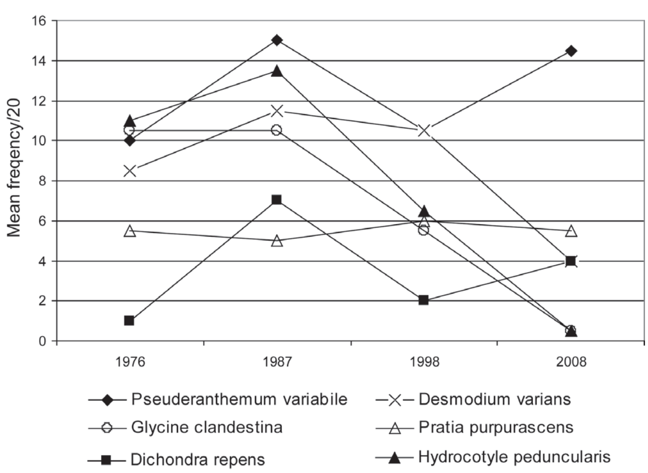

Fig. 4. Mean species frequency for individual groundlayer forb species at Blackwood (1976–2008) showing decrease for some (*Hydrocotyle*, *Glycine*) but relatively stable abundance for others.

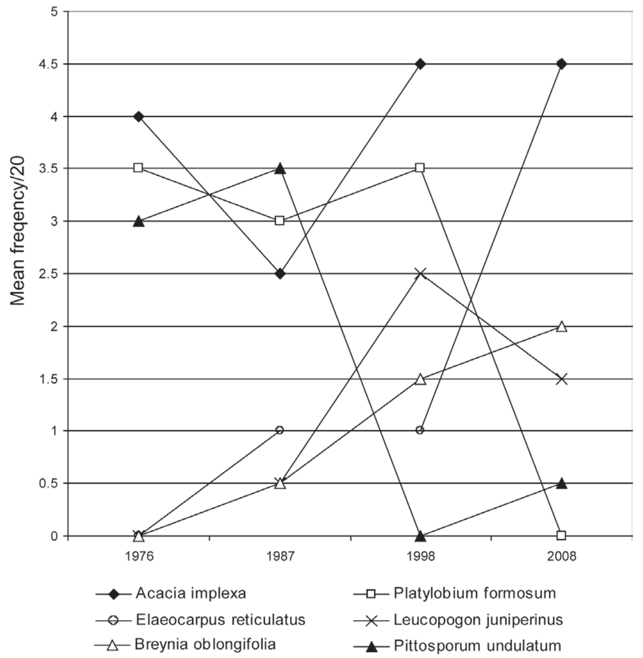

Fig. 5. Mean species frequency for individual shrub species at Blackwood over 30 year period (1976–2008) showing decreases for some species (*Pittosporum* – removed, *Platylobium*) but increases in others (*Elaeocarpus, Breynia Leucopogon*).

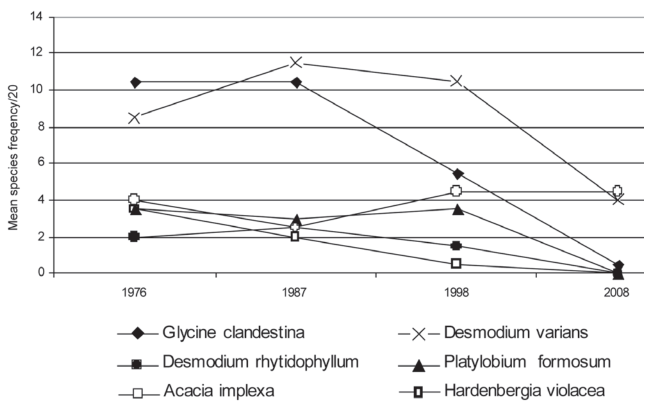

Fig. 6. Mean species frequency for individual Fabaceae species over 30 year period at Blackwood (1976–2008) showing decline of some (*Glycine, Desmodium, Hardenbergia, Platylobium*) but persistence of *Acacia implexa* as *Pittosporum* is cleared in 1980s, followed by decrease as vines form dense canopy.

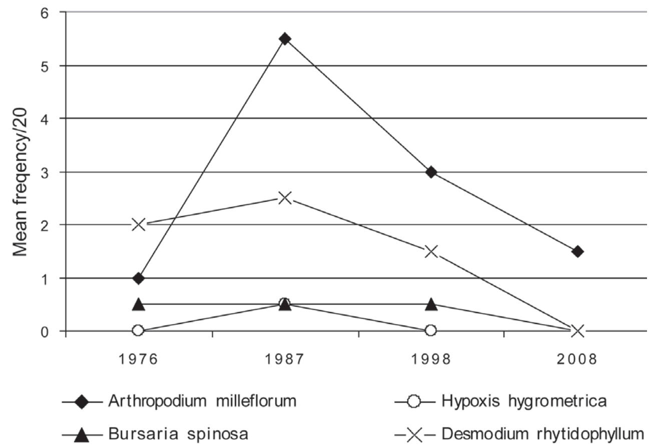

Fig. 7. Mean species frequency for individual long-lived conservation-significant species over 30 year period at Blackwood (1976–2008) showing decrease as vines form dense canopy.

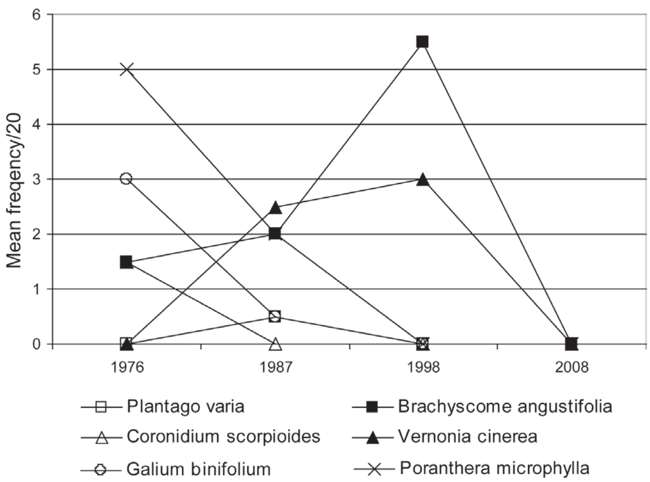

Fig. 8. Mean species frequency for individual short-lived conservation-significant shale species over 30 year period at Blackwood (1976–2008) showing decline of some (*Galium, Helichrysum, Poranthera*), but episodic increase for others (*Brachyscome, Vernonia)* as *Pittosporum* is cleared in 1980s, followed by decrease as vines form dense canopy.

than 1976, but groundcover forbs lower. Shrub frequency remained more or less constant over the 30 year period. The mean frequency of the significant shale species decreased. Overall vine and mesic shrubs have increased in frequency and dominance at the expense of the lower growing herbs and monocots.

Species changes over time

Though changes in growth-form groups give a picture of the coarse changes in vegetation, it is important to understand what is happening to species within each group as management responses will ultimately be aimed at particular species.

Figures 2–5 show changes over the 30 year period for the most frequent species in each of the growthform groups. Except for *Hardenbergia violacea,* all the vine species particularly *Pandorea pandorana, Clematis aristata, Cayratia clematidea* and *Eustrephus latifolius* have been increasing markedly since 1976 (Figure 2).

Of the frequent grass and graminoid species (Figure 3), most increased in frequency between 1977 and 1998 but then dropped, with some, in 2008, still above 1976 frequency.

Table 2. Blackwood monitoring study: native plant species with frequencies (max 20) in the two 20 m transects recorded at 10 year intervals from 1976 to 2008. Buchanan Indicator species noted #

Native species (Family)	Transect 1				Transect 3			
	1976	1987	1998	2008	1977	1987	1998	2008
Climbers/vines								
Cayratia clematidea (Vitaceae)	0	0	17	19	0	0	3	12
Clematis aristata (Ranunculaceae)	3	9	20	14	7	10	10	13
Eustrephus latifolius (Philesiaceae)	3	11	17	10	5	8	15	18
Geitonoplesium cymosum (Philesiaceae)	0	0	0	1	0	0	1	5
Hardenbergia violacea (Fabaceae)	3	4	1	0	4	0	0	0
Pandorea pandorana (Bignoniaceae)	3	9	15	16	5	10	15	15
Tylophora barbata (Apocynaceae)	0	0	0	0	0	5	9	18
Groundcovers grasses, graminoids								
# *Arthropodium milleflorum* (Anthericaceae)	1	5	3	2	1	6	3	1
Carex inverse Cyperaceae)	2	3	2	0	0	11	6	0
Dianella caerulea (Phormiaceae)	0	0	0	3	0	0	0	4
Dichelachne rara (Poaceae)	0	0	0	0	0	5	3	0
Digitaria ramularis (Poaceae)	0	0	0	0	0	0	0	2
Echinopogon caespitosus (Poaceae)	0	0	1	2	0	1	0	6
Entolasia marginata (Poaceae)	1	10	12	7	5	17	13	18
# *Hypoxis hygrometrica* (Hypoxidaceae)	0	0	0	0	0	1	0	0
Imperata cylindrica (Poaceae)	4	8	9	8	7	6	11	7
Lomandra filiformis (Lomandraceae)	0	0	0	1	0	0	0	0
Lomandra longifolia (Lomandraceae)	0	0	1	7	0	3	5	0
Lomandra multiflora (Lomandraceae)	0	2	1	0	0	0	0	0
Microlaena stipoides (Poaceae)	1	2	8	1	1	5	11	9
Oplismenus aemulus (Poaceae)	11	20	17	7	18	13	16	16
Poa affinis (Poaceae)	1	6	4	3	1	3	5	2
Groundcovers Forbs/ferns								
Adiantum aethiopicum (Adiantaceae)	0	0	0	0	0	0	0	6
# *Brachyscome angustifolia* (Asteraceae)	0	0	0	0	3	4	11	0
Brunoniella australis (Acanthaceae)	0	9	8	0	0	4	7	0
Centella asiatica (Apiaceae)	0	0	0	0	0	0	0	2
# *Desmodium rhytidophyllum* (Fabaceae)	0	0	0	0	4	5	3	0
Desmodium varians (Fabaceae)	13	17	17	2	4	6	4	6
Dichondra repens (Convolvulaceae)	2	7	0	1	0	7	4	7
# *Galium binifolium* (Rubiaceae)	6	1	0	0	0	0	0	0
Glycine clandestina (Fabaceae)	9	8	6	0	12	13	5	1
Goodenia hederacea (Goodeniaceae)	0	0	0	0	2	1	0	0
# *Coronidium scorpioides* (Asteraceae)	0	0	0	0	3	0	0	0
Hibbertia serpyllifolia (Dilleniaceae)	0	0	0	0	1	0	0	0
Hydrocotyle peduncularis (Apiaceae)	2	10	5	0	20	17	8	1
Opercularia varia (Rubiaceae)	0	1	0	0	0	1	0	0
Oxalis ? corniculata (Oxalidaceae)	1	1	0	1	9	3	6	2
# *Plantago varia* (Plantaginaceae)	0	0	0	0	0	1	0	0
Plectranthus parviflorus (Lamiaceae)	2	3	0	0	0	0	0	0
# *Poranthera microphylla* (Euphorbiaceae)	0	0	0	0	10	4	0	0
Pratia purpurascens (Lobeliaceae)	7	6	7	8	4	4	5	3
Pseuderanthemum variabile(Acanthaceae)	1	14	14	14	19	16	7	15
Pteridium esculentum (Dennstediaceae)	5	6	7	6	3	5	5	8
# *Vernonia cinerea* (Asteraceae)	0	0	5	0	0	5	1	0
Shrubs								
Acacia implexa (Fabaceae)	7	4	8	2	1	1	1	7
Acmena smithii (Myrtaceae)	0	0	0	0	0	0	0	2
Breynia oblongifolia (Euphorbiaceae)	0	1	2	2	0	0	1	2
# *Bursaria spinosa* (Pittosporaceae)	0	0	0	0	1	1	1	0
Elaeocarpus reticulatus (Elaeocarpaceae)	0	1	2	4	0	1	0	5
Leucopogon juniperinus (Epacridaceae)	0	0	0	2	0	1	5	1
Notelaea longifolia (Oleaceae)	0	0	1	0	0	0	0	0
Pittosporum undulatum (Pittosporaceae)	4	6	0	1	2	1	0	0
Platylobium formosum (Fabaceae)	0	1	0	0	7	5	7	0
Polyscias sambucifolia (Araliaceae)	0	0	1	5	0	0	0	0
Trees								
Angophora floribunda (Myrtaceae)	0	0	0	0	0	0	0	1
Eucalyptus pilularis (Myrtaceae)	0	0	1	0	0	0	0	2

These include the grasses *Entolasia marginata*, *Imperata cylindrica, Microlaena stipoides* and *Poa*. Both *Oplismenus aemulus* and the sedge, *Carex inversa* were below the 1976 frequency.

The frequent groundcover forbs have remained generally stable (*Pseuderanthemum variabile, Pratia purpurascens, Dichondra repens*) or decreased (*Desmodium varians, Hydrocotyle peduncularis, Glycine clandestina*) (Figure 4) (Table 2).

Although the shrub species as a group remained constant there was a change in species composition (Figure 5); some species such as *Platylobium formosum* and *Pittosporum* having decreased. More mesic species such as *Elaeocarpus reticulata* and *Breynia oblongifolia* and *Leucopogon juniperinus*, however, increased.

Fabaceae, a hard-seeded family, changes over time

Species in the Fabaceae family have generally done poorly (Figure 6). Despite the general increasing trend for vines, *Hardenbergia violacea* decreased over the 30 year period and was not recorded in 2008. Similarly the forbs *Desmodium rhytidophyllum* and *Glycine clandestina* and the shrub *Platylobium formosum* have decreased. Fabaceae species have hard-coated seeds which require heat for germination and have evidently not had suitable conditions for recruitment, although some species can regrow from rootstocks after disturbance.

Decrease of significant shale species

By 2008 the significant shale indicator species (Figures 7,8) have decreased markedly; only one, *Arthropodium milleflorum*, out of 10 species was recorded in the transects. Over the 30 years, some have been gradually declining (*Coronidium scorpioides*, *Poranthera microphylla, Galium binifolium*, *Bursaria spinosa*); others increased in response to the *Pittosporum* clearing and subsequently declined (*Arthropodium milleflorum, Hypoxis hygrometrica*, *Plantagovaria*), while others show a marked pulse in the 1998 recording (*Brachyscome angustifolia*, *Vernonia cinerea*), possibly related to good rainfall conditions following the hot summer. Some species still occur outside the transects, in previously mowed areas (*Galium binifolium, Bursaria spinosa*), though 6 were not recorded in a general recording of the reserve in May 2003 (Benson & Howell 2003) and may only exist in the soil seedbank, if at all.

Discussion

In 10, 50 or even 100 years this report can be used as the base line so that, if accurate records are kept, it will be known what management procedures have led to changes, if any, in the vegetation of the Sanctuary. (Robin Buchanan 1977)

In 1978, two decades before the formal listing of the Blue Gum High Forest as an Endangered Ecological Community, Buchanan recognised the conservation significance of the remnant of Wianamatta Shale flora at Blackwood. She highlighted the significance of the groundlayer species of heavy or deep soils such as *Vernonia cinerea, Sigesbeckia orientalis, Conidium scorpioides* and *Imperata cylindrica* which were mixed in with tall shrub species typical of sandstone gullies eg *Pittosporum, Acmena smithii, Myrsine variabilis* and *Allocasuarina torulosa*. The shale groundlayer species, highlighted in 1977 as being the most significant for conservation, have virtually disappeared (except perhaps in some of the previously mowed areas around the reserve margins).This is largely a result of management actions which have concentrated on weed removal but have not responded to associated changes in native species taking place, despite repeated calls based on the monitoring program.

Understorey dynamics in a grassy/shrubby open-forest understorey

Larger growing shrubs such as *Pittosporum* (and woody exotics such as *Ligustrum lucidum*) tend to outgrow and shade out smaller understorey species in the absence of disturbance (fire, drought, periodic grazing). Time frames relate to the longevity of the main structural species, the tall shrub *Pittosporum*, individuals of which are fire-sensitive and live about 30–40 years (Benson & McDougall 1999). (The exotic *Ligustrum lucidum* is fire-resistant and lives much longer). Conceivably in BGHF in the pre-European environment, local understorey dominance by *Pittosporum* over 30–40 years (in the absence of fire), and subsequent overgrowth by vines in the subsequent 20 years as the *Pittosporum* died out (at Blackwood of course removed prematurely), could have been a localised inter-fire event (occupying at least 60 years) in some particular moist /sheltered sites. There would be unlikely to be any change to the overstorey *Eucalyptus* species (which probably live 100–200 years) during this time. At the same time, in adjacent BGHF on sites not suitable for dense *Pittosporum* recruitment (either too dry, open, or subject to occasional burning or grazing), the grassy groundcover shale species could have predominated. As such these processes and mixtures of species are *natural*, but required the larger landscape to coexist.

However the problem in the 2008 context is that we have to manage for the long-term survival of all native species, and in particular a group of shale species of open sites, in only a small remnant (1.2 ha) of the original area of BGHF, and deal with the impacts of ecological processes that have previously operated at the landscape scale.

How resilient is the system?

Bushland sites include not only those species that are obvious in the existing above-ground vegetation. Many species have a soil-stored seedbank, supressed rootstock or soil-stored tubers. Some may be able to disperse into suitable habitat from adjacent areas.

Though the shale species were not recorded in the transects in 2008, *Sigesbeckia orientalis* is still present in Blackwood in disturbed sites. Several other species including *Vernonia cinerea* were recorded as abundant in 1998, with rain following a dry El nino year. These are short-lived species that are likely to remain in the soil seedbank; 10 years is not a long period of time for seed to remain. For example species of *Desmodium* and *Arthropodium* have germinated after 14 years in storage, and *Vernonia* after 12 years (Hong et al. 1998), though there is no data for the particular species at Blackwood.

What is needed is to maximise the variation in habitat patchiness within Blackwood so that conditions for a wider range of species are improved. In small reserves a mixture of treatments to enhance habitat variation is necessary if all species are to be conserved.

A program incorporating burning of relatively large areas, some regular mowing of trails and some less frequent coarser slashing of small areas may provide a wider range of microhabitat conditions for recruitment of species that are not currently evident, but may be present as soil-stored seed or rootstock. This needs to be done in concert with ongoing control of exotic weeds.

Lessons for monitoring from the Blackwood study

The simple fixed-transect vegetation monitoring program was efficient time-wise (though requiring expert identification ability) and demonstrated results over a 30 year period

It is necessary to record individual species changes over time. Species richness measures are of limited use for evaluating long-term changes, as new species appearances may be counterbalanced by existing ones disappearing, leaving measures showing no nett change though vegetation dynamics may have changed considerably.

Monitoring results need to be publicly available, as over the long-term different stakeholders are likely to take an interest, and ongoing recording is more likely to be maintained if earlier results are available.

Lessons from management at Blackwood

The conservation aims were clearly defined (conservation-significant species were highlighted), monitoring did provide a measure of the change after each 10 year recording, and subsequent recommendations were increasingly supported by data.

Management responded positively to the recommendations for the removal of *Pittosporum* and woody weeds in the 1980s.

However the recommended burns were never carried out. This was probably due to bureaucratic problems, such as lack of access to, or awareness of, the original reports, staff changes and physical difficulties, e.g. weather in arranging for the burns. Resolution for action was weakened by varying opinions on whether burning was really needed, generally without reference to the monitoring data.

Clearing of *Pittosporum* provided the physical effects of fire but did not provide the bare ground cover and heat treatments provided by fire. With the physical removal of the shrub canopy in the 1980s the vine component took over and spread as the main understorey canopy layer.

Recommendations in 2008 are for burning, as in 1987 and 1998, but more urgent, as suppressed plants and soil seedbank gradually deteriorate under the increasingly thick vine canopy.

Periodic monitoring of marked sites and observance of the trends are essential if we are to improve conservation outcomes in bushland reserves. While a single visit to the site would reveal the impacts of *Pittosporum* shading or weed invasion, the gradual rate of vegetation change, at least in terms of the shale species, was not obvious, especially in the absence of the monitoring data.

Conclusions

While we can't necessarily retain all native plant species in a small reserve in the long-term, it is important to understand the significant regional contribution that a small reserve can make and identify the species and components that should be prioritised for long-term management.

Monitoring of fixed plots at Blackwood at 10 year intervals over 30 years clearly documented the changes in the vegetation taking place. Important and repeated recommendations arising from these assessments were only partly implemented. Consequently the group of species identified as of particular conservation significance for this reserve may have been lost or are severely depleted. Whether they can be recovered remains unknown.

For the long-term management of biodiversity in conservation reserves, science and management need to work together if successful conservation outcomes are to be achieved.

Acknowledgements

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