Restoring Blue Gum High Forest: lessons from Sheldon Forest

By Tein McDonald, Kevin Wale and Virginia Bear

We know we must restore Blue Gum High Forest remnants — but how resilient are they to the urban impacts to which they have been exposed for decades? Responses to initial restoration trials provide a range of important clues.

Figure 1. Low intensity 'prescribed fire' at Sheldon Forest, Pymble, conducted by Ku-ring-gai Council as part of their ecological restoration trials for endangered Blue Gum High Forest. (Photo: National Herbarium)

The authors worked together in the Bushland Management Section of Ku-ring-gai Council (PO Box 15 Gordon, NSW 2072) from 1987 to 1991. Current addresses are ***Tein McDonald*** *(PO Box 42, Woodburn NSW 2471, Australia. Tel.: + 61 26682 2885 Email: teinm@ozemail.com.au),* ***Kevin Wale*** *(National Parks & Wildlife Service PO Box 1967, Hurstville, NSW 2220, Australia) and* ***Virginia Bear*** *(Baulkham Hills Shire Council, PO Box 75 Castle Hill NSW 1765, Australia).*

Sheldon Forest, located in Ku-ring-gai Municipality in Sydney's northern suburbs, contains a rare remnant of Blue Gum High Forest. In the late 1980s when our bush regeneration team first entered this degraded site, the normally pleasant tall open forest 'ambience' and our usual optimism was muted by the intense weed infestation. We were not afraid of the challenge of weed control, but this site had so little native vegetation left in the understorey we were unsure whether our usual 'assisted natural regeneration' approach would be applicable.

As there was very little of this forest type remaining, we carefully weighed up whether we should begin with at least some planting or cautiously try a natural regeneration approach. With support from our employers (Ku-ring-gai Council) and some advice from National Herbarium staff, we opted for a regeneration approach on the basis that we monitored the results of early treatments to guide future works.

Monitoring was something field regenerators were unaccustomed to, so we felt our way and designed and implemented a small field trial, comparing effects of manual and fire-assisted treatments with an untreated control strip. Monitoring continued over a 5 year period and demonstrated that abundant regeneration of many pre-existing species occurred, particularly where the effect of previous fires regimes was most closely mimicked. Similar patterns were also found at two other Blue Gum High Forest sites: Kitchener Road, Hornsby and Denistone Park, Ryde, as will be described in this article.

Box 1: Blue Gum High Forest

In Sydney, the Blue Gum High Forest — now listed as an Endangered Ecological Community under the *NSW Threatened Species Conservation Act 1995* — is estimated to have once covered some 4000 ha of the more fertile, higher rainfall shale soils along the Hornsby plateau on Sydney's 'north shore', extending from Crows Nest to Hornsby and west along the ridges between Castle Hill and Eastwood (Benson & Howell 1990a, 1990b). It is now restricted to about 36 ha remaining as relatively intact bushland in scattered small remnants (1% of its presettlement extent) with an additional 240 ha occurring as scattered trees.

Blue Gum High Forest is a moist tall open forest or open forest community with the dominant canopy trees Sydney Blue Gum (*Eucalyptus saligna*) and Blackbutt (*E. pilularis*). Other trees include Forest Oak (*Allocasuarina torulosa*) and occasionally Sydney Red Gum (*Angophora costata*). Understorey plants include Prickly Beard Heath (*Leucopogon juniperinus*), Narrow-leaved Geebung (*Persoonia linearis*) and Hop Bush (*Dodonaea triquetra*). At moist gully sites, rainforest species such as Cheese Tree (*Glochidion ferdinandi*) and Lillypilly (*Acmena smithii*) are common. The ground stratum is often dense and contains a mixture of herb, grass and fern species including Common Maidenhair (*Adiantum aethiopicum*), Right-angle Grass (*Entolasia marginata*), Mat Rush (*Lomandra longifolia*), Soft Bracken Fern (*Calochlaena dubia*), Flax Lily (*Dianella caerulea*), Pastel Flower (*Pseuderanthemum variabile*) and Basket Grass (*Oplismenus imbecilis*). Twiner species are also frequently present.

In any particular site not all of the species that can occur in Blue Gum High Forest may be present at any one time (at least above ground) and seeds of more species may be present in the soil seed bank. The species composition of a site will be influenced by the size of the site and by its recent disturbance history. For a number of years after a major disturbance, dominance by a few species may occur, with gradual restoration of a more complex composition and vegetation structure over time. The balance between species will change over the fire cycle, and may also change in response to changes in fire frequency.

Table 1. The characteristic assemblage of vascular plant species in the Blue Gum High Forest community. (Source: NSW Scientific Committee 1997)

Acacia implexa	*Eucalyptus saligna*	*Pandorea pandorana*
Adiantum aethiopicum	*Eustrephus latifolius*	*Persoonia linearis*
Allocasuarina torulosa	*Glochidion ferdinandi*	*Pittosporum revolutum*
Angophora floribunda	*Glycine clandestina*	*Pittosporum undulatum*
Billardiera scandens	*Goodenia heterophylla*	*Playtlobium formosum*
Blechnum cartilagineum	*Hardenbergia violacea*	*Poa affinis*
Brachycome angustifolia	*Helichrysum scorpioides*	*Polyscias sambucifolius*
Breynia oblongifolia	*Hibbertia scandens*	*Poranthera microphylla*
Calochlaena dubia	*Imperata cylindrica*	*Pratia purpurascens*
Clematis aristata	*Indigofera australis*	*Pseuderanthemum variabile*
Clematis glycinoides	*Kennedia rubicunda*	*Pteridium esculentum*
Clerodendrum tomentosum	*Leucopogon juniperinus*	*Rapanea variabilis*
Commelina cyanea	*Leucopogon lanceolatus*	*Rubus parvifolius*
Dichondra repens	*Lomandra longifolia*	*Smilax glyciphylla*
Echinopogon caespitosus	*Microlaena stipoides*	*Syncarpia glomulifera*
Elaeocarpus reticulatus	*Notelaea longifolia*	*Themeda australis*
Entolasia marginata	*Omalanthus populifolius*	*Tylophora barbata*
Eucalyptus paniculata	*Oplismenus aemulus*	*Zieria smithii*
Eucalyptus pilularis	*Oxalis exilis*	

[This material was adapted from information provided in NSW Scientific Committee (1997) and NSW National Parks and Wildlife Service (2000).]

How degraded was the Sheldon Forest site before treatment?

Sheldon Forest is a relatively narrow strip of bushland in the upper catchment of Avon Creek, a tributary of the Lane Cove River in suburban northern Sydney (Fig. 2). The reserve was purchased by Ku-ring-gai Council in 1948 in response to a campaign by the Pymble South Turramurra Progress Association for more public land to be set aside from development (Ku-ring-gai Council, corr., 1946). It stretches from the main Northern Sydney shale soil ridge towards the valley floor, transecting a range of soil types and supporting a range of plant communities. Blue Gum High Forest, a tall open forest type dominated by Sydney Blue Gum (*Eucalyptus saligna*) and Blackbutt (*E. pilularis*) (Box 1), occurs on the highest point where shale soils are deepest.

When we commenced work in the 1980s, the Blue Gum High Forest section of Sheldon Forest was highly degraded. It had a thinning canopy of eucalypts, an insignificant cover of natives on the ground and a mid-storey dominated by a high density of exotic shrubs. Fire had been excluded for at least five decades and there appeared to be very little, if any, eucalypt recruitment or evidence of an understorey flora that might be characteristic of a previously existing fire-adapted sclerophyll community (Table 1). The most abundant of the exotic shrubs were Large-leaved Privet (*Ligustrum lucidum*), Small-leaved Privet (*Ligustrum sinense*), Camphor Laurel (*Cinnamomum camphora*), Lantana (*Lantana camara*), Ochna (*Ochna serrulata*) and Indian Hawthorn (*Raphiolepis indica*).

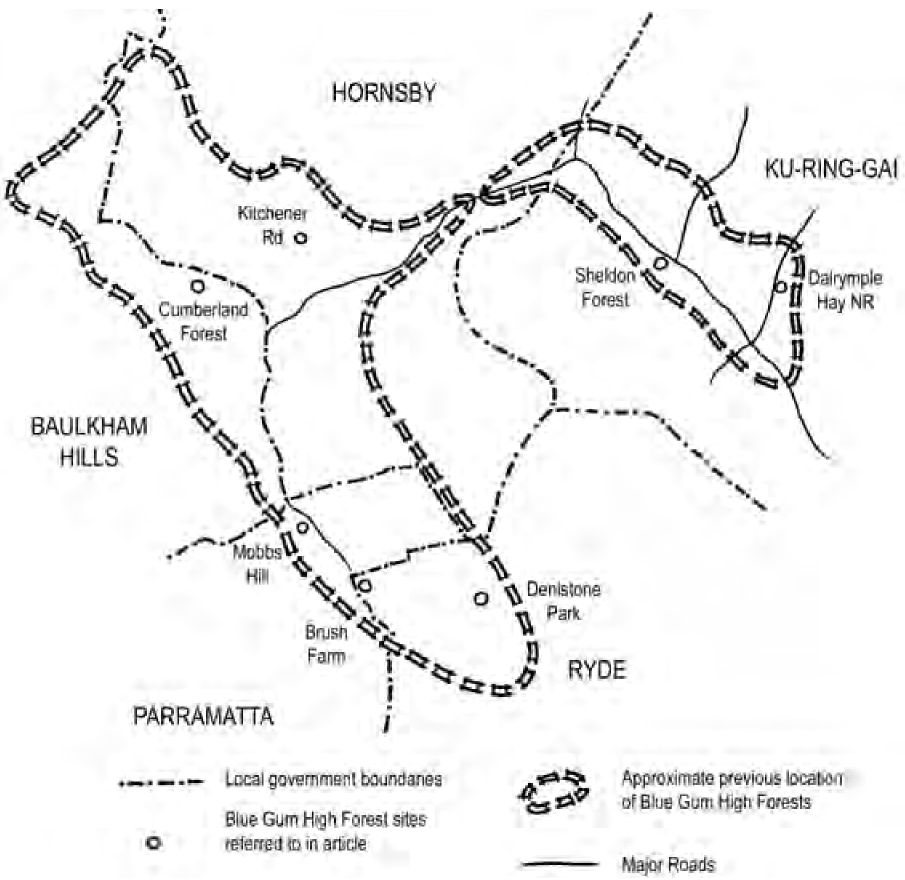

Figure 2. Diagrammatic representation of the approximate previous range of Blue Gum High Forest and location of the remnants referred to in this article. Land use history of the ridges in which this forest type was found involved selective harvesting of many of the forests' valuable timbers followed by clearing of the flatter sites for agriculture and later, housing. Some clearing for housing developments is still occurring although the vegetation type is listed as an Endangered Ecological Community under the *NSW Threatened Species Conservation Act 1995*.

On closer inspection, the native shrub Pittosporum (*Pittosporum undulatum*) was also dominant in the mid-storey, although exotic shrub species were about three times more abundant. This fire-sensitive native, naturally occurring along the creekline, probably colonized the higher areas of the site during the last 50 years when fire had been excluded or suppressed for safety reasons and where a range of new ecological conditions prevailed (Adamson & Fox 1982; Rose 1997). Birds, including Pied Currawongs (*Strepera graculina*) whose diet includes Pittosporum and a range of exotic shrubs common in nearby gardens (Buchanan 1989), would not only have dispersed Pittosporum to the higher elevation sites but would also have dispersed seed of the exotic garden shrubs into the Pittosporum stands. This process appeared similar to shifts from 'xeric' to 'mesic' vegetation (in the absence of fire and in the presence of urban weed) described by Adamson and Buchanan (1974) and Adamson and Fox (1982).

Closer inspection also revealed that the understorey included 42 native groundcover species including grasses, forbs and ferns; as well as 18 native sclerophyll shrubs and subshrubs (Table 2). Exotic groundcovers were very rare. The natives were so sparsely distributed, however, that it was difficult to determine the understorey's previous structure. Was it predominantly made up of ferns (as many descriptions of 'wet sclerophyll forest' elsewhere record); was it composed mainly of grasses and forbs; or, were sclerophyll shrubs more predominant (as may occur after a more intermediate fire frequency on drier sites)?

The answers to these questions were difficult to assess. As historical records describing prior land use were scant and, as all nearby Blue Gum High Forest sites were weed infested, we did not know what a healthy Blue Gum High Forest understorey should look like. Rather than undertake planting based on speculation about prior composition, we hoped that our regeneration approach might allow us

Table 2. Understorey species present in a small quantities prior to treatment at Sheldon Forest

GROUNDCOVERS		
Perennial grasses/sedges	**Perennial forbs**	*Pseuderanthemum variabile*
Cyperus gracilis	*Arthropodium* sp.	*Veronica plebea*
Digitaria parviflora	*Brunoniella australis*	*Viola hederaceae*
Entolasia marginata	*Desmodium* sp.	
Imperata cylindrica	*Dianella* spp.	**Annual forbs**
Microlaena stipoides	*Dichondra repens*	*Galium* sp.
Oplismenus aemulus	*Glycine* sp.	*Sigesbeckia* sp.
Panicum simile	*Oxalis corniculata*	*Solanum* sp.
Poa affinis	*Pratia purpurascens*	
SCLEROPHYLL SHRUBS AND SUB-SHRUBS		
Acacia decurrens		
Acacia floribunda	*Daviesia ulicifolia*	*Leucopogon lanceolata*
Acacia implexa	*Dodonaea triquetra*	*Ozothamnus diosmifolius*
Acacia longissima	*Gonocarpus* sp.	*Platylobium formosum*
Acacia stricta	*Hibbertia aspera*	*Xanthosia pilosa*
Acacia ulicifolia	*Indigophora australis*	*Zieria smithii*
Bursaria spinosa	*Leucopogon juniperimum*	

to 'read' the past from the site's residual species and soil seed bank. Assuming the soil was undisturbed and could function as a 'time capsule'; we anticipated that we might discover which species were most likely to have comprised the forest understorey and in what relative proportions they might have occurred.

As well as this, we were hoping that our trials might contribute to testing the degree to which 'assisted natural regeneration' treatments, applied in Sydney for decades, might help achieve restoration. In the early 1970s, Joan Bradley had hypothesized that a site's capacity to recovery naturally is often higher than managers expect, suggesting that restoration should focus on removing impacts and facilitating natural regeneration (Bradley 1988). More recently, Walt Westman and others had articulated concepts of 'ecosystem resilience' (Westman 1978; 1986; Fox & Fox 1986); with Westman (1985) hypothesizing that resilience (developed through adaptation to natural disturbances) might assist managers restore sites affected by human-induced disturbances and other impacts. Little formal testing of this hypothesis had been carried out by researchers or field practitioners to date.

Treatment options

'Minimal disturbance' weed control techniques (i.e those that minimize disturbance of the soil) were the main techniques used in Sydney at the time. These often resulted in strong recovery of the herb layer (particularly stoloniferous species) but only sparse regeneration of sclerophyll shrubs. Was that because the shrubs had died out or were their seeds stored in the soil and simply not provided with the right cues to germinate? Bearing in mind that many scleropyll plants are disturbance-adapted, might more 'optimal disturbance' approaches, based on the ecological requirements of species of the pre-existing plant communty, be worth a try?

Fire had recently been recommended to reduce the fire-sensitive Pittosporum and to stimulate the regeneration of sclerophyll species at another northern Sydney site (Blackwood Sanctuary, Pennant Hills) where little regeneration had occurred after the control of exotics alone (Buchanan 1978; 1987). With advice from Robin Buchanan (Ryde TAFE) and Doug Benson (Royal Botanic Gardens) we decided to compare regeneration after fire-assisted treatments and regeneration after manual treatments alone.

How we conducted the trials

We selected a trial 1.5 ha area which was more or less homogeneous in soil, aspect,

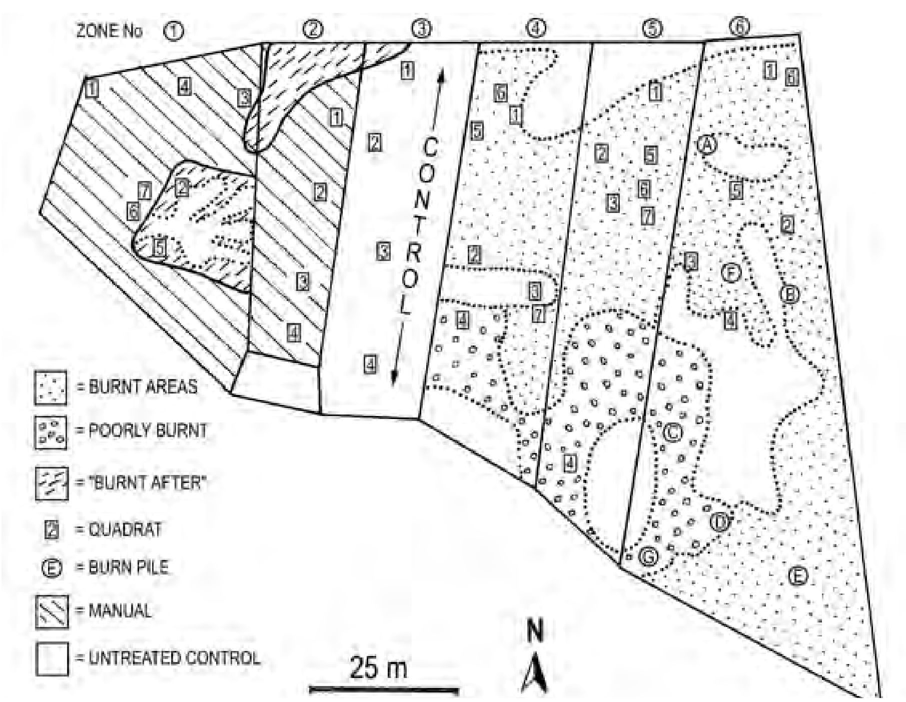

Figure 3. Site diagram of Sheldon Forest regeneration trials. Six zones were treated with either predominantly manual treatments (zones 1–2) or predominantly fire-assisted treatments (zones 4–6). Zone 2 was inadvertantly burned half way through the monitoring program, providing additional trial areas for the effect of burning postweeding regrowth. Average annual rainfall at Sheldon Forest is about 1444 mm. (Adapted from diagram by Kevin Wale from data provided by Ku-ring-gai Council.)

slope and vegetation; and divided this into zones. We used two of the zones (1 and 2) for manual clearing treatments commencing at different times; Zone 3 was left untreated to function as a control; and, a prescribed burn was conducted in the three remaining zones (Zones 4–6). (Fig. 3)

'Manual' weed treatments conformed with those commonly used in the bush regeneration industry at the time (later described in Wright 1991). All 'non-pullable' saplings were treated with glyphosate 360 g/L cut stump treatment and taller specimens were treated by stem injection. This was supplemented with hand pulling of saplings and seedlings.

At the time of the prescribed burn, we also carried out two other types of burn: a small, smoky prescribed burn in a small section of grassy regrowth in Zone 1 (duplicated accidentally 3 years later in another section of Zone 1); and, burns of piles of debris (mainly Pittosporum). These 'fire piles' contained a high proportion of larger (10–20) diameter stems as well as small (< 5 cm) diameter fuel.

The prescribed burn was conducted in spring 1989, by Ku-ring-gai Council, using standard fire hazard reduction techniques. Because of the low fuel load at ground level prior to the fire, we found it helpful to fell some Pittosporum to increase the fuel load near the point of ignition. The fire was still described, however, as generally of low intensity (D. Benson, pers. comm., 1990). After the fire, we poisoned any resprouting or unburnt exotic shrubs and Pittosporum.

How we monitored

We undertook two separate monitoring exercises (Table 3). The first monitoring exercise was carried out before and on three occasions after treatment (over five growing seasons) using small fixed quadrats (4–9 m^2). The second monitoring exercise was carried out at the end of the five growing seasons, using unfixed, larger quadrats (25 m^2). In both sets, native species richness (i.e. number of species per quadrat) and density of stems were counted at each of four height strata (< 0.5 m; 0.5–2 m; 2–5 m and > 5 m). By 5 years after the treatment, two of the control quadrats had been inadvertently burnt, so control data could not be include in the last reading. In addition, we less formally recorded all species that germinated around the fire piles.

Table 3. Treatments and numbers of quadrats used in the regeneration trials at Sheldon Forest

Times and duration of monitoring	Treatment	No. quadrats	Quadrat size
Before and up to 5 years after (four readings)	Manual only (two different dates)	10	4 m^2 and 9 m^2
Before and up to 5 years after (four readings)	Prescribed fire followed by manual	13	9 m^2
Before and up to 5 years after (four readings)	Fire pile followed by manual	7	6 m^2
Before and up to 5 years after (four readings)	Untreated control	4	4 m^2
5 years after treatments	Manual only (two different dates)	16	25 m^2
5 years after treatments	Prescribed fire followed by manual	17	25 m^2
5 years after treatments	Manual followed by fire ('burnt after')	5	25 m^2
5 years after treatments	Untreated control	5	25 m^2

What came up after treatment?

A diverse native flora regenerated across all the treatments (Fig. 4), including representatives from all three groups: mesic shrubs (those normally occurring in moist communities such as rainforest), sclerophyll shrubs, and groundcovers (twiners, grasses, forbs and ferns). After 2 years and a number of follow-up weed control treatments, high levels of native vegetation cover re-established across the site, making future planting redundant.

Shrubs

Of the nine shrubs that were most prolific in their recovery, two were mesic shrubs, Elderberry Panax (*Polyscias sambucifolius*) and Bleeding Heart (*Omalanthus populifolius*), while the other seven were sclerophyll shrubs (including six acacia species). The most common sclerophyll shrubs were Black Wattle (*Acacia decurrens), A. longissima* and White Dogwood (*Ozothamnus diosmifolius*). Sclerophyll shrubs that germinated less prolifically were Hop Bush (*Dodonaea triquetra*) and Sandfly Zieria (*Zieria smithii*) which germinated in isolated clusters. *Platylobium formosum* and *Xanthosia pilosa* germinated sparsely.

While scleropyll shrubs regenerated after both fire and manual treatments, they germinated prolifically around the fire piles. No germination occurred in the centre of the piles where temperatures were hottest and the fire burnt for over an hour.

While no new species, additional to the original 69, were recorded across the site after treatment, sclerophyll shrubs were considerably better distributed after treatment. At the beginning of our trial, sclerophyll shrubs occurred in only seven of the 25 (4–9 m^2) permanent quadrats read before treatment, but sclerophyll shrubs had germinated in 20 of these quadrats after the range of treatments. A measure of the spread of individual sclerophyll shrub species across the site 5 years after treatment is given in Table 4 (expressed as a percentage, to accommmodate the difference in the number of quadrats available for each treatment).

Groundcovers (grasses, forbs, ferns and twiners)

Groundcover herbs (forbs and grasses) regenerated well after all treatments (except on fire piles) and soon reproduced and spread. There were 24 species that were particularly prolific, with the most common forbs, twiners and grasses listed in Table 5. (All plant species names are consistent with Harden 1990, 1991, 1992, 1993.)

The increase in groundcovers peaked after approximately 2 years before declining in similar proportion to the increase in cover of shrubs and climbers on the quadrats. This effect was most pronounced

Figure 4. Photographic monitoring at Sheldon Forest shows (a) virtually bare ground (in zone 1) 3 months after manual removal of exotic shrubs and Pittosporum; (b) high groundcover regeneration (same photo point) 2 years after treatment; (c) higher levels of sclerophyll shrub regeneration in a burn area (zone 6) nearly 5 years after treatment. No planting was carried out on site.

on the fire-treated quadrats. It was also significant that exotic herbaceous species were rare.

Mechanisms of recovery

By careful observation, we could identify if an individual plant regenerated by germination or resprouting. Of the shrubs, only Hickory Wattle (*Acacia implexa*) resprouted and all others appeared to have germinated from soil-stored seed. Irrespective of treatment, basket grasses (*Oplismenus* spp.) and Weeping Grass (*Microlaena stipoides*) germinated from seed (as did the right-angled grasses, *Entolasia* spp. although these also resprouted). Four other grass species germinated less frequently, or expanded vegetatively as in the case of Bladey Grass (*Imperata cylindrica*). Among the forbs, Pastel Flower (*Pseuderanthemum variabile*) recovered vegetatively, but Kidney Weed (Dichondra repens), *Desmodium* sp., Flax Lily (Dianella sp.) and Native Bluebell (*Wahlenbergia* sp.) germinated.

Weeping Grass germinated in the absence of mature specimens on burnt sites; and the basket grasses only germinated in the absence of parent plants after manual treatments. Annual forbs were too sparse to determine any response to treatment; but virtually all were located on quadrats where they previously did not occur, suggesting they arose from the soil seed bank.

Over time, much of the grass cover appeared to arise from seed produced from previously regenerated parent plants. By 12 months, for example, the initially sparse *Poa affinis* and Right-angle Grass (*Entolasia marginata*) proliferated; while *Panicum simile* was not found on the site until 18 months after treatment (but may have been on site) and subsequently spread. Flax Lily gradually increased over time after all treatments (having germinated and spread vegetatively) and *Lomandra* spp. declined in the quadrats treated by prescribed burn.

What did we learn?

The regeneration potential of the site turned out to be high, demonstrating that

Table 4. Percentage of the total number of quadrats (per treatment) in which a species occurred 5 years after treatment at Sheldon Forest. (The number of quadrats in which the species occurred is given in parentheses)

Species	Control (five quadrats)	Manual (16 quadrats)	Prescribed burn (17 quadrats)	Burnt regrowth (five quadrats)
Acacia decurrens	0% (0)	75% (12)	76.5% (13)	100% (5)
Acacia floribunda	40% (2)	6.25% (1)	41% (7)	20% (1)
Acacia implexa	0% (0)	6.25% (1)	6% (1)	20% (1)
Acacia longissima	0% (0)	12.5% (2)	29.5% (5)	60% (3)
Acacia stricta	0% (0)	0% (0)	6% (1)	100% (5)
Acacia ulicifolia	0% (0)	12.5% (2)	0% (0)	100% (5)
Bursaria spinosa	0% (0)	0% (0)	11.75% (2)	0% (0)
Daviesia ulicifolia	0% (0)	0% (0)	0% (0)	40% (2)
Dodonaea triquetra	0% (0)	0% (0)	0% (0)	20% (1)
Gonocarpus sp	0% (0)	6.25% (1)	64.75% (11)	0% (0)
Hibbertia sp	0% (0)	43.75% (7)	47% (8)	80% (4)
Indigophora australis	20% (1)	0% (0)	6% (1)	0% (0)
Leucopogon juniperimum	0% (0)	43.75% (7)	23.5% (4)	60% (3)
Leucopogon lanceolata	0% (0)	6.25% (1)	0% (0)	0% (0)
Ozothamnus diosmifolius	0% (0)	75% (12)	53% (9)	80% (4)
Platylobium formosum	20% (1)	18.75% (3)	6% (1)	60% (3)
Xanthosia pilosa	0% (0)	16% (4)	6% (1)	20% (1)
Zieria smithii	0% (0)	0% (0)	6% (1)	40% (2)
% of possible species-quadrat combinations	4.2% (4/95)	17.4% (53/304)	20% (65/323)	42% (40/95)
Total number of species/treatment (out of 19 species)	3	12	14	14

Table 5. The most common groundcovers regenerating and subsequently spreading at Sheldon Forest after treatment

FORBS
- Pastel Flower (*Psuederanthemum varibile*)
- Kidney Weed (*Dichondra repens*)
- Native Oxalis (*Oxalis corniculata*)
- Whiteroot (*Pratia purpurascens*)
- Native Geranium (*Geranium homeanum*)
- Mat Rush (*Lomandra longifolia*)
- Fine-leaved Mat Rush (*L. filiformis*)
- Flax Lily (*Dianella* sp.)

GRASSES
- Weeping Grass (*Microlaena stipoides*)
- Right-angle grasses (*Entolasia* spp.)
- Basket grasses (*Oplismenus* spp.).

TWINERS
- *Glycine* sp.
- *Desmodium* sp.
- Wombat Berry (*Eustrephus latifolius*)
- Headache Vine (*Clematis glycinoides*)
- False Sarsaparilla (*Hardenbergia violaceae*)
- Red Kennedy Pea (*Kennedia rubicunda*)
- Wonga Wonga Vine (*Pandorea* spp.).

the capacity of the site to regenerate could not be predicted by the level of weed or native cover before treatment. Resorting to planting on the basis of low numbers of natives and high numbers of weeds, therefore, would have been a mistake. Had we undertaken plantings on the basis of assumptions current at the time, we may have introduced inappropriate species; an important point considering the degree of uncertainty about our site's original floristic composition.

While no new species were recorded on site, the abundance of both herbaceous species and sclerophyll shrubs was a surprise, suggesting that the pre-existing understorey was likely to be generally composed of a mixture of sclerophyll shrubs, grasses, forbs, twiners and some dry area ferns. Moist-area ferns and mesic shrubs were less well-represented, even in the unburnt areas. This regeneration indicated that the soil seed banks of many species was apparently intact, possibly because these species are adapted not only to periodic disturbances but also to somewhat extended periods without disturbance.The low recovery of *P. formosum* and *X. pilosa*, however, suggested a lack of long-term viable seed banks; or perhaps fire temperatures were not optimal for germination of these species.

Was the use of fire important?

In terms of comparing 'minimal disturbance' bush regeneration treatments against the perhaps more 'optimal disturbance' prescribed burns and burn piles, we found that treatments involving fire had a significant effect. All three fire types initially resulted in an increase in abundance of sclerophyll species, although there was a decrease in abundance of these shrubs over 5 years in the prescribed burn sites. This may have been due to thinning of excessively high densities of seedlings over time or an increase in germination in the manually treated areas over time. This was a significant finding because it showed that even low levels of disturbance are sufficient to trigger germination of at least some individuals. The significant difference between fire and manual treatments, however, persisted in association with burn piles (where patches of higher density sclerophyllous species were still present after 5 years) and in areas where regrowth from manual treatments was subsequently burnt (see Box 2).

Practical feasibility of treatments

Documentation of the person-hours spent undertaking the treatments showed us that the prescribed burn could halve the cost of manual clearing of Pittosporum. About 50–75% of the Pittosporum within the burnt zone was killed outright by the

Box 2: Did the use of fire improve regeneration?

Effect over time. Significantly higher increases in species richness and density of sclerophyll shrubs were found in fire-treated quadrats compared to manually treated quadrats, using fixed 4–9 m^2 quadrats ($P < 0.05$). Differences persisted for density over the 5 years but not species richness except in the fire pile treatments (Fig. 5). There was an increase in sclerophyll shrub density over time on the manually treated sites as well as decrease on the fire sites. Sclerophyll shrub species did not increase in the controls over time. We found no statistical differences between richness or density of groundcover species regenerating after fire compared to after manual treatment alone.

Effect at 5 years. A highly significant difference in sclerophyll shrub richness and density was found after 5 years (using the 25 m^2 quadrats) in the case of the manual/fire treatment ($P < 0.05$) which was better represented in this data set (Fig. 6). This treatment (involving burning of herbaceous regrowth after preliminary manual weeding) would need to be tested, however, over more subsites and replicated at other sites to reliably say whether this is an effect of the treatment as opposed to an effect of the normal species 'patchiness' that may occur on these sites.

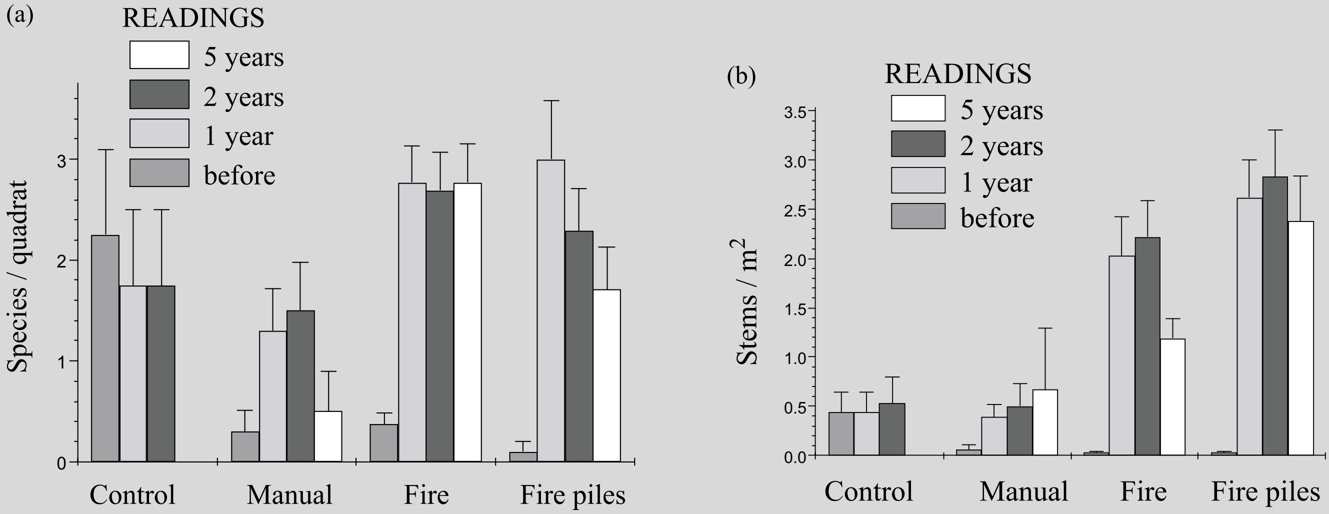

Figure 5. Effect (over time) of treatments on (a) the mean number and (b) density of sclerophyll shrub species occurring per 4–9 m^2 quadrat at Sheldon Forest. (Bars represent standard error.) Note that higher numbers of sclerophyll shrubs occurred on the randomly selected controls before treatment compared to the treated areas.

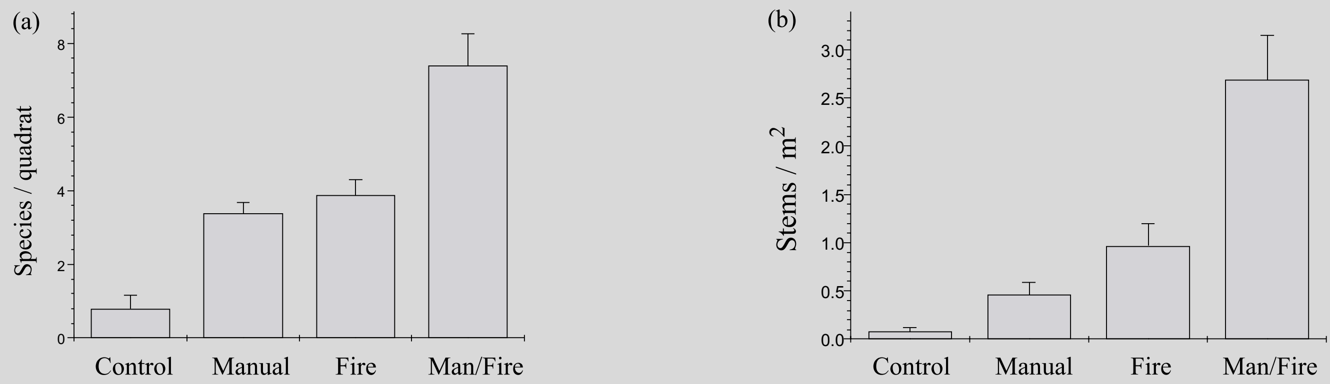

Figure 6. Effect (after 5 years) of a range of treatments on (a) the number of sclerophyll shrub species per 25 m^2 quadrat and (b) the density per m^2 at Sheldon Forest. The 'man/fire' treatment was burning of post-manual regrowth. (Bars represent standard error.)

fire and did not require subsequent injection with herbicide (K. Wale, pers. obs., 1990). Prescribed burns therefore may be valuable as a pretreatment in degraded sites where sufficient fire intensity is achieved and if there is a commitment to follow-up control of exotics.

The trial demonstrated that the *prescribed burn* was feasible in a site dominated by weed, but it also highlighted some logistical difficulties. The moist nature and low fuel levels made it difficult for the site to support a fire. In addition, there is only a narrow 'window of opportunity' during late Spring or early Autumn when weather conditions allow a hotter burn that is still controllable. This reduced options for organizing burn treatments and presented considerable programming difficulties. These were overcome, however, by cooperation between the fire hazard reduction team and the bush regeneration team; and we were fortunate to have favourable weather. These logistical difficulties raise the question of whether prescribed 'ecological' burns might be better employed at earlier stages in healthier sites where they may be more easily applied, rather than waiting until the site becomes degraded and largely incombustible.

Our trials showed, however, that *pile burns* and/or *burning post-regeneration herbaceous regrowth* may offer practical alternatives to prescribed burns for sites of low combustibility. Pile burns were found to be a relatively easy way of creating localized clusters of sclerophyll shrub species. This may assist with increasing the representation of a range of genetic material on site. The piles to be burnt do not need to be large, however, since we observed that piles of over 1.5 m in height burnt at such an intensity and for such a duration that the soil seed bank underneath appeared to be killed by the fire.

Burning post-treatment herbaceous regrowth showed the highest sclerophyll regeneration results of all the treatments (Table 4 and Box 2). This may have been due to chance floristic differences as only five (25 m^2) samples were available for this treatment type and soil seed banks may well be patchy in nature. However, the frequency and density increases for these sites were so high that it is possible that the results do indicate more ideal regeneration conditions provided by the treatment. One possible explanation is that the slower, smoky burns (as the green hebaceous regrowth produced a fairly slow, smokey fire) may well achieve higher temperatures at critical soil depths to trigger germination of a range of species; or the smoke itself may have triggered germination. This approach warrants further experimentation.

Implications for the management of Blue Gum High Forest sites

Only a small number of Blue Gum High Forest remnants occur in the Sydney area. Most of these occur in two local government areas (Baulkham Hills and Hornsby), with very small numbers in six other local government areas. These remnants are all highly vulnerable to further fragmentation; clearing for development; increased nutrient status; inappropriate fire regimes; invasion by exotic plants; and, edge mowing. All sites except the few under active management are affected by severe competition from mesic shrubs and decline in understorey sclerophyll shrubs and herbaceous species. Only one remnant, Dalyrymple Hay Nature Reserve, is protected in the National Parks estate, although some occur in Public Open Space bushland or areas directly owned by government bodies. Most occur in zonings (e.g. residential and rural) that generally allow some development to occur. About 28% of the best condition Blue Gum High Forest vegetation (i.e. that with greater than 10% canopy cover and area greater than 0.5 ha) occurs in land zoned rural, while 36% occurs in land zoned residential.

The Sheldon trials demonstrate that active management of Blue Gum High Forests can considerably improve their condition and long-term viability. The trials demonstrated that soil seed banks had persisted despite decades of weed invasion and fire exclusion. This resilience probably derived from naturally longer interfire periods (accompanied by shifts to more mesic species) observed in higher fertility sclerophyll ecosystems elsewhere (Fraser & Vickery 1939; Unwin 1989).

Despite the links with natural patterns of 'mesic shift' however, recovery will not occur without active management. In particular, reversal of this shift to mesic species will not occur merely with the reinstatement of fire. This is because potential for hot fires is reduced by landscape level fragmentation and because many of the exotics are likely to persist after a cooler fire and will soon outcompete natives in a postfire recovery phase. Restoration therefore must involve detailed and thorough weed control combined with sufficient disturbance to trigger germination of natives from the soil seed bank. The disturbance of weed control itself may be sufficient in many cases, although the incorporation of fire at Sheldon Forest demonstrated a significant benefit.

The resilience demonstrated at Sheldon Forest, however, must not be interpreted as leeway for managers to delay treatment. Lower resilience levels were found at sites subject to more intense or longer degradation (Box 3). The partially cleared and grazed Denistone Park site, for example, is likely to have lost species; and even the most resilient (soil stored) species, such as acacias, lose resilience over time and are likely to have a maximum of 70–100 years storage life from the date of the last inputs to the soil seed bank (Auld 1987). Most of our older urban edges, particularly the earlier-developed shale sites, are rapidly approaching that age threshold, and the threshold may be passed for many species less resilient than acacias. This is particularly the case for perennial forbs and grasses and other species that do not form persistent seed banks at all. What we do in the next decade therefore is likely to be critical if these important remnants are to be adequately conserved.

Future actions?

At the completion of our trials in 1996, our results were formally presented at workshop (organized by Environs Australia and funded by Land and Water Research and Development Corporation) directed towards managers of Blue Gum High

Box 3: Similar results of treatments at other Blue Gum High Forest sites

During the period of monitoring at Sheldon Forest, monitoring was undertaken at two other, similarly sized Blue Gum High Forest restoration sites undergoing similar types of treatments; Kitchener Road, Hornsby and Denistone Park, Ryde. While overstorey trees were still intact at these sites, their understoreys were highly dominated by weed shrubs, with Large-leaved Privet the main mid-storey weed at Kitchner Road and Lantana the main weed at Denistone Park.

Weed removal resulted in the virtual bareing of the ground at both sites, followed by massive regeneration by a range of species (Fig. 7). Significantly higher sclerophyll shrub regeneration occurred after weed control and the use of fire piles at Kitchener Road compared to weed control alone, although a wide range of species regenerated across all treatments (Table 6). Medium-sized fire piles did not produce regeneration at Denistone Park but significantly higher Acacia regeneration occurred after very high intensity pile burns, probably because the seed banks at the long-grazed Denistone Park were older and perhaps more deeply buried than at either Kitchener Road or Sheldon Forest (McDonald 1996).

A striking difference between the three sites is that lower levels of sclerophyll shrub recovery occurred at Kitchener compared to Sheldon Forest, and still lower levels occurred at Denistone Park. This, and the fact that many more 'additional' species appeared after treatment at Kitchener Road and Denistone Park compared to Sheldon Forest (Table 6), indicated that both sites were more degraded than Sheldon Forest at the time of treatment. This may be explained by different pre-existing floristics at the three sites but could equally well be explained by a spectrum of increasing degradation with Denistone Park (where the density and frequency of occurrence of many species was considerably lower) being the most degraded. This would make sense as Kitchener is more exposed than Sheldon Forest to urban impacts and there is evidence that Denistone Park was cleared, burnt and grazed for dairying during the late 19th and early 20th centuries prior to reverting to a Lantana understorey.

Figure 7. Photographic monitoring at Denistone Park shows (a) virtually bare ground remaining after manual removal of thickets of Lantana dominating the understorey, and (b) very high regeneration 2.5 years after treatment. Black Wattle prolifically germinated in areas subjected to hot burn piles and Poison Peach (*Trema tomentosa* var. *viridis*) prolifically germinated in areas treated manually.

Table 6. Changes in number of (a) sclerophyll and (b) total species found at three Blue Gum High Forest sites before and after treatment

	Before	After
SCLEROPHYLL		
Sheldon	18	14
Kitchener	0	11
Denistone	2	5
ALL SPECIES		
Sheldon	68	69
Kitchener	43	65
Denistone	38	59

Box 4: Active management of Blue Gum High Forest gradually increasing

At the time of writing, a range of activities are being undertaken by individual State and local government managers of Blue Gum High Forest and at least one private corporation, IBM Australia. While all recognize that potential for increasing these works exists, most managers are committed to priority management for this and other Endgangered Ecological Communities and most if not all have expressed an interest in some form of regional Blue Gum High Forest management group.

Ku-ring-gai Council. Maintenance is continuing at Sheldon Forest and a fire was conducted at Browns Forest, Pymble in April 1997 after herbiciding the Lantana in advance so it would dry out sufficiently to burn. The area has been maintained by Council's regen team ever since. A site at Canisius Close, Pymble, was also burned in December 2000 after poisoning Privet and Pittosporum and the site has since been maintained by Bushcare volunteers.

Ryde Council. Works have continued at Denistone Park and plans are in train to conduct another burn in the northeast corner of the Park. Regeneration works have also occurred at Brush Farm Park, Darvall Park and Burrows Park (where burns have been conducted) and new works are planned for other sites. Council looks forward to upgrading the pace and effectiveness of Blue Gum High Forest works in the Shire.

Hornsby Council. Regeneration work at Kitchener Road has been carried out by the site's Bushcare group, and good regeneration results have occurred at Hull Road and Rosemead Road sites after manual treatments. Excellent results occurred at Dog Pound Creek (Westleigh) after fire and contract regeneration works. Trials are also being planned to examine invertebrate recovery after a range of treatments at Kitchener Road and Rosemead Road and more work is planned for other remnants, including rural Tim Brownscombe Reserve in Galston.

Baulkham Hills Council. An accidental burn in Richard Webb Reserve, Pennant Hills in 1995 resulted in good regen including peas, acacias and epacrids, with follow-up undertaken by the Bushcare Group. Manual weeding has been undertaken by contractors at Richard Webb Reserve and Mt Wilberforce Lookout. Pile burns could be used more extensively on these sites. A restoration program is to commence soon in Heritage Park, Castle Hill, involving ecological burning and pile burns, with follow-up by contractors and volunteers.

State Forests of NSW. Blue Gum remnants in Cumberland State Forest have become very degraded in the last 10 years. Disproportionate numbers of Bell Miners (*Manorina melanophrys*) are also a serious problem, possibly due to excessive Lantana in the understorey. Trials have been conducted using mechanical disturbance followed by regeneration weeding, resulting in wattles and grasses not apparent before. Fire piles have been used more recently on a trial basis.

Sydney Water. Castle Hill Reservoir is a major Blue Gum High Forest site not yet actively managed, but Sydney Water is preparing a plan for the site, recommending use of fire with appropriate follow-up weeding.

Northern Area Health Service. Some initial works were undertaken in the mid-1990s at the Ryde Hospital remnant through the LEAP scheme. Opportunities exists for further and important works similar to programs carried out by the Northern Area Health Service in other Endangered Ecological Communities in the area.

IBM Australia has engaged a bushland manager who, over the last few years, has overseen manual clearing of exotics in their significant Blue Gum High Forest remnant. Initial results from recent fire piles have been encouraging and they are interested in using more fire if practicable. There appears to have been an increase in wrens and Whip Birds (*Psophodes olivaceus*) during this time, and Bell Miner numbers have decreased. A landscape management plan is in preparation and will be recommending ongoing resource allocation to the bush regeneration program.

National Parks and Wildlife Service undertook a successful regeneration burn at Dalrymple Hay NR in April 1997 followed up by weed control. A management plan that involves ecologically appropriate fire regime and regular bush regeneration treatments has been completed.

Forest in the Sydney area. The aim of the workshop was to provide practical restoration models and to advocate for a concerted restoration effort. Since that date, many land managers have increased their active involvement in restoration of Blue Gum High Forest remnants (Box 4) and most express an interest in making more significant inroads in the next 5 years and beyond.

The constraints to sigificant progress, however, are very real. Funding for bushland management is limited and it is often difficult for managers to apply fire in sites 'landlocked' by residential areas. In gully sites, including some Bushcare sites, piles have rotted before the burn could be arranged. Furthermore, burning of debris piles is difficult for managers who do not have their own fire units and who need to rely on metropolitan or rural fire brigades for whom pile burning is not a high priority.

One action that might help managers overcome some of these constraints is the potential for managers to form a regional Blue Gum High Forest management group or even a Conservation Management Network (CLM) (as described by Prober *et al*. 2001). Such a group could allow local government, State government (including Sydney Water and State Forests) and private landholders to share expertise and information, set restoration targets and collectively seek funding to achieve the more significant conservation of this Endangered Ecological Community (see Box 4). It is hoped that restoration action will also be stimulated through the *Cumberland Plain Endangered Ecological Communities Recovery Plan,* the preliminary draft of which sets best-practice standards for bushland management, and proposes that all remnants of Blue Gum High Forest on public land be managed to these standards. This includes requirements for bush regeneration, appropriate fire regimes and management of other impacts, where feasible (NSW National Parks and Wildlife Service, unpubl. data, 2002).

Our take-home message is that managers need to think carefully about the impact of, intentionally or unintentionally, excluding appropriate levels of disturbance and weed control in the management of healthy Blue Gum High Forest or the repair of degraded bushland. To do so may be allowing these communites to shift towards depauperate systems dominated by exotic shrubs. Our results show that the argument, 'but these sites have changed irrevocably anyway', is not a reasonable excuse. The residual recovery potential of many sites shows that they have not been permanently changed, but that recovery potential may be quietly waiting for an appropriate level of disturbance and systematic weed control. If left too much longer, however, this chance is likely to disappear forever and the restoration of these sites will depend on complex, costly and difficult reconstruction from an increasingly limited gene pool.

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