RESTORATION OF WINGHAM BRUSH 1980–1996

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Summary The remnant rainforest at Wingham Brush was smothered in weeds and dissected with roads and tracks. Australia's first attempt to restore a rainforest started at Wingham in 1980. The impacts of flying-foxes, climate and humans are discussed in relation to retention of the forest. The development of glyphosate application techniques for aggressive exotic vegetation formed the basis of the program's success. The major goal in rainforest restoration is gaining a weed-free canopy and closing it. Continual maintenance weeding is required to ensure native succession and the forest's survival.

INTRODUCTION

Wingham Brush is located adjacent to the township of Wingham along the Manning River on the mid-north coast of New South Wales. The remnant comprises 9 ha of lowland subtropical rainforest classified by Floyd as Suballiance No. 3, which was 'the major suballiance on the well-drained, fertile, basaltically enriched alluvial floodplains north from the Manning River'. Less than 100 ha remain in New South Wales, with 'today's remnants… pitiful bases in an agricultural desert' (Floyd 1990). The Brush includes two other dry rainforest alliances on its borders (Figure 1), substantially cleared for residential and recreational development (Stockard 1992). Together with Coocumbac Island Nature Reserve (5 ha) downstream at Taree, these remnants are the most southerly representatives of their type.

Although 1300 mm annual rainfall is generally required to support subtropical rainforest, mean rainfall for Wingham is only 1100 mm, with droughts commonplace. In 15 years, 1981–1995, ten totals were below average, with five of these below 900 mm. Many tree species in the Brush respond to drought, becoming semi-deciduous. The remnant is a major maternity site for the grey-headed flying-fox (*Pteropus poliocephalus* Temmink) and an occasional camp for the little red flying-fox (*Pteropus scapulatus* Peters) both, in varying degrees, also impacting on the canopy.

The remnant forest was divided into three portions by two unsealed roads with power lines, and dissected by an additional vehicular track. A brick toilet block with concrete steps intruded into the forest. The perimeter was unfenced and a proliferation of trails crisscrossed the interior.

The Brush had a history of neglect and abuse and was overrun with exotic vegetation. Plantings of exotic trees also diminished its scientific value. In 1978 Floyd noted that the Brush would be lost within 50 years under its current management. He was probably optimistic.

The first formal attempt to restore a rainforest in Australia started at Wingham in 1980 under the direction of the National Trust of Australia (NSW). Work commenced using the Bradley Method, but this method was inapplicable to this rainforest environment and a new method was formulated by the local team using glyphosate (Floyd and Dodkin 1984). On average, the team comprised six regenerators, each working four hours a week, with funding provided by the Greater Taree City Council.

Vines of South American origin, *Macfadyena unguis-cati* (L.) A. Gentry, *Anredera cordifolia* (Ten.) Steenis and *Cardiospermum grandiflorum* Sweet were the principle canopy pests. The floor of the forest was carpeted with *Trandescantia albiflora* Kunth, also of South American origin.

Macfadyena is an ornamental with showy yellow flowers. It invaded and spread in sunny areas as well as

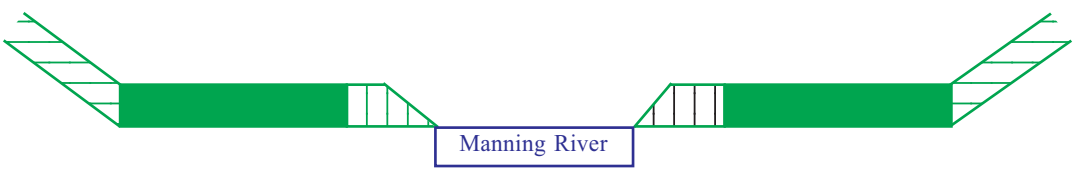

Figure 1. Diagram of rainforest Suballiances bordering the Manning River at Wingham prior to European settlement. dry rainforest, Suballiance No. 26: *Waterhousea floribunda*, *Tristaniopsis laurina*. subtropical rainforest, Suballiance No. 3: *Cryptocarya bovata* R.Br., *Dendrocnide excelsa*, *Ficus* spp., *Araucaria*. dry rainforest, Suballiance No. 28: *Backhousia sciadophora* F. Muell., *Dendrocnide*, *Drypetes*.

under heavy shade. Stems on the ground produced tubers every 30–50 cm which acted as centres for further growth which then behaved the same, weaving a net over the ground. Silt deposits from floods resulted in a layering of infestation. Tree trunks were often completely covered with stems. An infested tree 1.5 m circumference hosted 560 vines, the largest measuring 15 cm diameter. The vines smothered the canopy, crowns broke apart under the weight, and massive root competition finished off the host, which finally toppled to the ground as a 'green pole'.

Anredera is a fleshy-leafed vine originally cultivated as a purgative. Although not producing seed in Australia, clumps of propagative tubers are produced along the stems and yam-like tubers below ground. An average aerial cluster weighed 75 g, containing 35 tubers, with huge clusters attaining 1650 g and containing 850 tubers. Underground tubers reached weights of 130 g. One thousand five hundred tubers per square metre occurred on the surface under heavily infested canopies. The vine is shade-inhibited, but increased light from canopy disturbance resulted in an explosion of growth from the tubers. Growth rates can exceed one metre a week in the main growth period, October–April.

As *Macfadyena* increasingly destroyed the canopy, the resulting increased light advantaged *Anredera* which then dominated *Macfadyena.* Canopy destruction accelerated with the rampant growth of the heavier *Anredera.*

Cardiospermum was largely restricted to edge situations. Curtains of this vine consisted of many small stems woven together to form a dense, impenetrable wall which collapsed the forest margin inwards, thereby decreasing the forest area.

Tradescantia mats prevented the emergence of most seedlings and varied from 6 to 60 cm in depth depending upon light. It is capable of scrambling up 1.5 m. A square metre of 40 cm depth contained about 30 000 nodes. As the vines killed the trees and the forest collapsed, this ground cover ultimately smothered the vines. A luxuriant 40–60 cm expanse of *Tradescantia* represented the climax of reverse succession from weed incursion.

METHODS

Macfadyena vines were cut with loppers or secateurs about 1.5 m from the ground. The vines were pulled back from the bark of their host, and then tied in bundles with a flexible portion of vine. Undiluted glyphosate was applied immediately after recutting. Vines under 1 cm diameter reshot more commonly than larger ones, and these benefited from also stripping one side 10–15 cm from the cut before herbicide application. Subsequent regrowth was coiled and placed on the ground away from valued vegetation before spraying with glyphosate.

Initially, *Anredera* vines were cut, but they dramatically proliferated aerial tubers, and the tubers remained viable suspended in the canopy, slowly raining down for years afterwards. It became apparent that where vines cannot be completely removed from the canopy, they are better left unsevered. A 20–30 cm length of stem is freed from tubers and scraped with a knife to expose the interior on one side, with undiluted glyphosate immediately brushed in for several seconds. On horizontal sections, vines thicker than 2.5 cm were opened up with a knife, or sections cut from them to form wells for greater herbicide uptake. This allowed herbicide to be translocated through the tuber network. Terrestrial tubers which will receive increased light can be raked into piles away from valued vegetation to compost and topspray in future.

Where vines could be entirely removed, they were placed on the ground and later sprayed along with the shooting tubers.

Cardiospermum curtains were cut with brushhooks or secateurs. When the vines reshot about 0.5 m they were sprayed with glyphosate. Other minor edge vines like *Passiflora subpeltata* Ortega, *Araujia hortorum* Fourn. and *Lantana camara* L. were treated in the same way. Larger vines were cut and painted or scraped and painted if bearing green fruit. This treatment was particularly useful for *Araujia* with green pods.

Seedlings of *Cardiospermum* are prolific but easily removed by hand or sprayed. Fresh seed is enclosed in an inflated capsule which floats. The hard, black seeds continued to germinate below infested edges 11 years after initial treatment. Raking the surface detritus below infestations into piles may succeed in composting some of the seed as well as limiting seedling distribution.

Tradescantia mats blocked most seedlings. It was left intact until the canopy reformed after vine clipping. The stock of short-lived *Macfadyena* seeds was largely exhausted within 12 months under *Trandescantia* mats. When the canopy adequately shaded the ground, the mats were sprayed when manpower was adequate for the subsequent seedling selection. Exotic seedlings, especially *Ligustrum sinense* Lour., *Ligustrum lucidum* Arton, *Cinnamomum camphora* (L.) Nees, *Cestrum parqui* L'Her., *Ochna serrulata* (Hochst.) Walp., *Murraya paniculata* (L.) Jack., and others were manually selected from the native regeneration. *Tradescantia* spraying was most effective late autumn-winter.

Cut and scraped vines were painted with a 25 cm width paintbrush and undiluted glyphosate. Glyphosate spray equipment ranged from 15 L backpack in the early years to a 2 L handsprayer during the last two seasons. Effective spray concentrations ranged from 2% for *Trandescantia, Cardiospermum, Araujia, Passiflora* and *Lantana* to 5% for *Anredera* and *Macfadyena.* The

addition of 1 mL of Herbi-dye™ to each litre of spray solution as a marker was very useful. The addition of 2 mL of Codacide Oil™ to each litre of spray solution helped cover the shiny foliage of *Anredera* and *Trandescantia. Anredera* required a monthly spray cycle for control during its main growth period.

Some regrowth from *Anredera* and *Macfadyena* has been very persistent, surviving 11 years of cyclic spraying. Large underground tubers produced thin and weak shoots under the reformed canopy. This weak top growth provided an inadequate surface area for herbicide uptake relative to tuber mass.

Glyphosate concentrations were eventually increased to 25% during March 1996 and this appears to have achieved success in most of the stubborn regrowth. This heavy concentration was applied with a 2 L handsprayer with an average of 2.5 L of solution being used during four hours of work. Since 15 May 1995, 5 mL of LI-700™ was also added to each litre of solution.

In addition to glyphosate spraying, many man-hours were spent digging out underground tubers of *Anredera* during winter periods, using trowels and garden forks. Many of the narrow tubers passed under and around tree roots and were impossible to completely remove. Some years yet may be required to finally exterminate these last tubers.

DISCUSSION

All trees and shrubs were released from exotic vines by July, 1987 with glyphosate spray applied to regrowth since then. Glyphosate requirements have steadily declined from 160 L in 1984 to less than 20 L annually at present.

The aerial tubers of *Anredera* have shown an amazing ability to stay alive after vines were cut. A violent hailstorm 23 October 1987 largely defoliated the Brush, but thankfully brought down most of the suspended *Anredera.* A nest of tubers stranded after its parent vine was cut in 1984 was discovered this year in a fork of a tree blown down in a storm December 1995. These tubers sprouted vigorously when they reached the ground in the resulting canopy gap.

Solanum mauritianum Scop. is a prolific South American soft-wooded colonizer (Stage II) of gaps and open areas after spray treatment. The canopy of *Solanum* inhibits the rampant annuals (Stage I) which can overwhelm rainforest seedlings. Both secondary (Stage III) and primary (Stage IV) rainforest species establish under *Solanum.* This occurs because *Solanum* is a heavy fruiter and attracts frugivores which act as vectors of seeds from the adjacent forest. As *Solanum* is shade-intolerant and short-lived, it has been valuable in the regeneration cycle.

During the flood 4 February 1990, however, two shortcomings emerged. Firstly, the lack of ground cover under *Solanum* canopy in the Suballiance No. 26 region left the soil exposed after the weak root systems were torn out by floodwaters. This resulted in serious erosion. Secondly, *Solanums* died *en masse* throughout the Brush after inundation and they collapsed in a tangled mass which provided ladders for exotic vines to climb and became an obstacle course for the regeneration team.

Since then, *Solanum* has been removed from the Brush. The Suballiance No. 26 region was planted with *Waterhousia floribunda* (F. Muell.) B. Hyland, *Tristaniopsis laurina* (Smith) Peter G. Wilson & Waterhouse, *Callistemon viminalis* (Sol. ex Gaertner) G. Don ex Loudon, *Eucalyptus grandis* W. Hill ex Maiden and *Casuarina cunninghamiana* Miq. at a 2–3 m grid. *Waterhousia* and *Tristaniopsis* stock were grown in 20 cm diameter pots to an average height of 1 m before planting out in the thick annuals. In areas of scouring, they were planted 10–20 cm deeper than usual. The plantings had to battle floods, frosts and waves of annuals. During the flood 6 March 1995 the dense annuals among the plantings successfully held the soil. The worst frost in 25 years on 21 July 1995 froze many young trees to the ground, but most resprouted.

In gaps and open areas within Suballiance No. 3, *Dendrocnide excelsa* (Wedd.) Chew was successfully transplanted from areas of closing canopy where this light-demanding species (Stage III) was doomed. As well, other secondary and some primary species have been nursery grown and planted to bypass the *Solanum* phase.

Where tree planting was undertaken, genetic integrity was maintained by using local stock, much of which was propagated from the Brush. With no mature *Toona ciliata* M. Roemer remaining in the Brush after logging last century, a special effort was made to reintroduce this species.

A few thousand little red flying-foxes usually camp at the Brush from two to four weeks most summers. The canopy is heavily damaged by their habit of huddling together and on each other so that large limbs are broken by their combined weight. Canopy recovery generally occurs within 12 months, with damaged areas requiring careful maintenance to prevent weed reinfestation. Relatively small areas were variously damaged by these bats until the summer of 1995 when an estimated 450 000 arrived and stayed three months, devastating the mid-range canopy and lowering it 3–4 m through most of the Brush. This large influx is thought to have been caused by the drought forcing these wide-ranging bats from the inland. The annual Wingham rainfall for 1991 was 819 mm,

1992 was 897 mm, 1993 was 812 mm, and 1994 received only 508 mm, the driest year recorded since readings began in 1888. The canopy of the Brush was thin and the trees stressed. Recovery of the stressed and damaged canopy is proceeding, helped by the increase in rainfall (1284 mm in 1995), but two years may be required before the original shading is regained. Dormant *Anredera* sprouted in the high light levels, along with *Araujia, Passiflora, Cestrum, Solanum,* annuals, and native seedlings, particularly *Dendrocnide excelsa.* Labour requirements were high in areas previously needing only yearly inspection.

The impacts of grey-headed flying-foxes are much less, but canopy is thinned where they roost. Populations vary widely from year to year according to the available food supply, with drought triggering flowering in nearby *Eucalyptus* forests and attracting larger populations than wet years. Although some flying-foxes overwinter, numbers are highest from October to April. *Ficus macrophylla* Desf. is a popular roosting species and supports large populations without much damage. The more brittle *Dendrocnide excelsa* is also popular, and bats strip leaves and break branches, but the trees recover during the May–September period, encompassing their fruiting time. Grey-headed flying-foxes prefer to roost where the canopy is discontinuous or damaged and they often reoccupy sites damaged by little reds, which retards canopy recovery.

A large number of rainforest fruits are consumed by grey-headed flying-foxes and seeds may be transported by them from a distance of 40 km from their camps, connecting isolated remnants to other rainforest gene pools (Eby and Palmer 1991). Selected propagation material may be considered within this radius for remnants where flying-foxes reside.

Two roads with power lines and a vehicular track have been closed. The track was closed in 1980. The first road (Isabella Street) was closed, with the power placed underground and the surface ripped in 1986. The remaining road (Combined Street, S.) was rerouted and power removed with the surface ripped in 1993. Later that same year the toilet block and concrete steps were demolished. These road closures and demolition were followed with plantings to join the divisions of the Brush, thereby minimizing edge effects and improving the edge-core ratio (Buchanan 1979). Edges of remnant rainforest are vulnerable to weed invasion and require more maintenance than intact core areas.

The external fencing of the residential edges with a man-proof fence was funded by a Bicentennial Grant in 1987. Shortly before fence construction, millable exotic trees on the Brush perimeter were harvested by a local timber company. The 12.2 m^3 of *Cinnamomum camphora, Araucaria bidwillii* Hook. and *Carya* sp. yielded a net profit of $A1467 for the restoration program. Other large exotics have been poisoned with undiluted glyphosate applied to tomahawk cuts in the trunks, including rainforest trees native to other areas of New South Wales, such as *Castanospermum australe* Cunn. & C. Fraser ex Hook. and *Grevillea robusta* Cunn. ex R.Br.

In the Suballiance No. 26 zone treated pine fencing was erected to delineate the Brush boundary and exclude stock, vehicles and council slashers. The majority of this fence and a small portion of the chainwire fence was destroyed by the flood of 1990. Subsequently a strained wire fence was erected to replace the lost section. A significant portion of this fence was then torn out by the flood of 1995, which dragged the fence through the plantings like a chain, pulling over most of the *Eucalyptus grandis.* The other species, with their more flexible stems, fared better. Cattle entered the Brush anyway, driven to higher ground by a neighbouring landowner, leaving deep hoof prints in the saturated ground. Future plans are to install a row of low posts to mark the Brush boundary from the mown footpath.

The perimeter fence was successful in restricting access to designated entry points and also as a barrier against the dumping of garden refuse, which was common at the start of the program. The internal walkway, which includes two short boardwalks, was railed with treated pine, successfully keeping the greater majority of tourists from wandering through indiscriminately. The walkway was mostly constructed by volunteer labour from the local Rotary and Apex Clubs. Vandalism, particularly by truant students from the adjacent high school, is an ongoing problem, with posts and rails dismantled and broken. Signage suffers likewise.

Floods reintroduce weeds, particularly *Tradescantia,* which can rapidly reform mats. Often the introduced strands of this weed are partly covered with silt or rack or intermixed with annuals and glyphosate concentrations are increased to 5% for control. The Suballiance No. 26 edge, with its frequent rate of inundation, and lower and thinner canopy potential, is managed as a buffer zone with aggressive spraying to keep *Tradescantia* mats from reforming which would then grow into, or be swept by flood into the rare Suballiance No. 3 core. During floods, the forest margin screens out rack and vegetative propagules, with the upstream and riverine edges requiring the major maintenance attention afterwards.

All edges freed from exotic vines expanded without evidencing dieback. The released canopy responded by projecting outwards to form a convex veranda, and trees regenerated under that projection with the assistance of weeding.

CONCLUSION

The essence of rainforest restoration is to achieve a weed-free canopy, close it, and keep it closed. A thick, healthy canopy encourages the establishment of primary (Stage IV) species and discourages weeds. The succession within large gaps and cleared areas can often be hastened by assisting the establishment of secondary species (Stage III). The use of glyphosate is essential to control aggressive weeds which would otherwise interrupt the succession and threaten the viability of the forest. Importantly, a flexible approach is necessary in the shifting rainforest environment.

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