Long-term revegetation of a denuded area in the Sydney region

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Morrison, David A., McCluskey, Lesley and Houstone, Michael A. (Department of Environmental Biology & Horticulture, University of Technology Sydney, PO Box 123, Broadway, New South Wales, Australia 2007) 1995. Long-term revegetation of a denuded area in the Sydney region. Cunninghamia *4(1): 45–62.* A 3 ha area near Yanderra, New South Wales, where the plant and soil cover had been completely removed in 1918 to expose the underlying sandstone rock surface was examined in 1989, 71 years after the initial disturbance (and had also been examined in 1923 and 1962). The area has remained more or less undisturbed since 1918, and the revegetation has been allowed to proceed unhindered. In total, 108 species were encountered in and around the area, 92 of them occurring in the denuded area (18 of which were found only along the disturbed strip next to the adjacent railway line) and 16 found only in the adjacent undisturbed native vegetation. Twelve of these species are not native to the area, but only one of these occurs there outside of the railway strip. There were no consistent patterns of plant species composition within the denuded area, although many of the plants occurred in clumps. The most significant environmental factor influencing the distribution of the plant species within the denuded area was soil depth, with a number of species having increased abundance in areas with deeper soil. There was a clear distinction between the plant species composition of the denuded area and the adjacent undisturbed area, with 17% of the native species encountered not occurring in the denuded area and a further 16% showing a significantly lower abundance in this area. The soil structure and fertility both showed significant differences between the native area and the denuded area. There has been a large change in the floristic composition of the denuded area through the 71 years of revegetation, although the rate of change has apparently decreased in recent years. However, the floristic composition of the denuded area does not appear to be becoming more similar to the adjacent undisturbed area.

Introduction

Primary succession is usually defined as the replacement through time of one group of species by another on substrates with no previous history of biota (Miles 1979). The best-known examples include newly-exposed debris around active volcanoes and retreating glaciers, although examples from rock faces, fellfield, sand-dunes and saltmarsh are also known (Miles & Walton 1993). The temporal trends in floristic composition observed during primary successions are usually thought of as being quite different from the temporal trends in plant dynamics of vegetated areas (secondary successions and fluctuations), and they are likely to be a response to quite different environmental factors. The factors that are generally considered to be important in primary successional dynamics include nitrogen deficiency, substrate instability, and lack of an indigenous seed source (Miles & Walton 1993).

Australia is almost completely unglaciated and is tectonically relatively stable, and so the opportunities for studying primary succession are relatively limited. However, human disturbance often results in the exposure of virgin surfaces, which can act as substrates for colonisation. This paper reports the results of a study of a 3 ha area near Yanderra, N.S.W., which had its plant and soil cover completely removed in 1918 to expose the underlying rock surface. This area has remained more or less undisturbed since that time, and the revegetation has been allowed to proceed unhindered. Our study was conducted in August and September of 1989, 71 years after the initial disturbance.

Earlier stages of the revegetation process on the denuded area have previously been reported, including studies in 1923 by Cambage (1923) and 1962 by Hannon & Evans (1963), but there appear to have been no recent detailed studies. Our study seeks to answer five general questions: 1. What is the pattern of plant species composition on the denuded area? 2. Does this pattern relate to any environmental factors? 3. What is the pattern of plant species composition between the denuded area and the adjacent undisturbed area? 4. Does this pattern relate to any environmental factors? and 5. What has been the temporal pattern of plant species composition since the area was denuded?

Geographic setting

Yanderra (34°19'S, 150°34'E), approximately 110 km south-west of Sydney, is on the dissected sandstone plateau of the Nepean Ramp between Bargo and Mittagong. The surrounding vegetation is typical Sydney sandstone dry sclerophyll forest (Beadle 1981). The immediately surrounding area is relatively undisturbed, being mainly public land surrounding the upper reaches of the Bargo River to the north-west and the catchment of the Nepean Reservoir immediately to the south-east.

During the construction of the main southern railway line from Picton to Mittagong in 1916–1918, areas adjacent to the line were excavated to supply construction fill. The largest excavated area, immediately west of Yanderra, is 3.2 ha, forming the segment of a circle of 350 m radius and having a chord of 500 m (Figure 1). The railway line forms the circumference of this circle, and a fence (erected immediately after the clearing) forms the chord running NE–SW, bordering an area of undisturbed native vegetation. Approximately 1–1.5 m depth of soil was removed from the area, leaving the exposed rock with a slope of about 2% from the adjacent undisturbed area towards the railway line.

Most of the denuded area has remained relatively undisturbed since excavation. A dirt vehicular access track runs around the circumference inside the railway line, and the line is elevated above this track for nearly half the circumference (Figure 1). The narrow area between the line and the track is extremely disturbed, and was excluded from our study (as was the track), leaving a study area of about 460 m along the fence and about 100 m from the excavation embankment at the widest point (c. 2.5 ha; Figure 1). Small areas (c. 4% of the study area) near the junction of the circumference and chord at each end were cleared in the early 1980s and used as construction stockpiles, and these areas were also excluded from sampling (Figure 1). There is no evidence of any major disturbance in the adjacent area of native forest.

The surface features and topography of the denuded area were described in detail by Hannon & Evans (1963), and their description largely remains current. However, the series of stone-covered ridges that they reported is less in evidence than it apparently was. The plants present on the area 5 years after the excavation are listed by Cambage (1923), and Hannon & Evans (1963) report those present 39 years later. Various unpublished floristic lists have been produced since then, including one by D. Benson and H. Fallding in 1979, and one by S. Krauss and D. Mackay in 1984.

Materials and methods

Plant data

The floristic composition was determined from fourteen 10 m x 10 m quadrats in the denuded area and five similar quadrats in the adjacent vegetation (Figure 1). In the denuded area, five of the quadrats were placed in a line parallel to the fence and about 15 m from it , with about 100 m between the quadrats. Another line of five quadrats was placed a further 15 m from the fence, three quadrats were placed another 20 m from the second line, and one quadrat was placed a further 20 m from this line. Within the native vegetation, the five quadrats were placed in a line parallel to the fence and about 20 m from it.

The abundance of each vascular plant species was estimated for each sample using the nested-quadrat technique of Outhred (1984), with importance scores assigned to each species in each quadrat using seven square sub-quadrats varying from 1 to 100 m^2. This technique produces abundance scores (on a scale of 1–7) that are functionally equivalent to frequencies (Morrison et al. 1995), which are directly related to plant density (Bonham 1989).

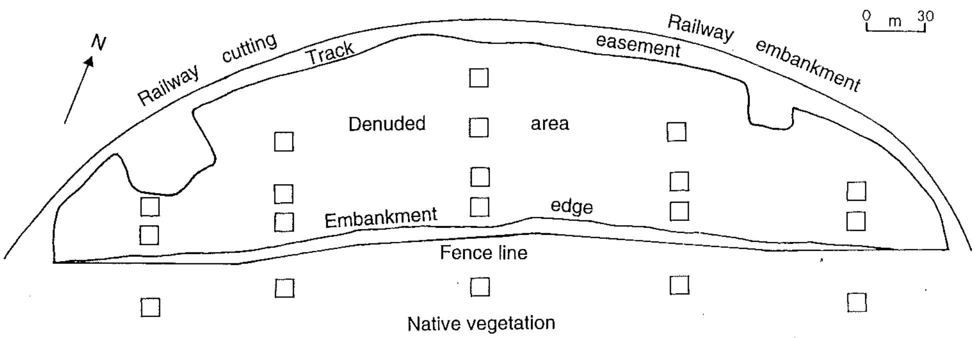

Fig. 1. Map of the study area at Yanderra. The squares indicate the location of the 14 quadrats used for the determination of floristic composition.

All plants in the denuded area that were taller than 2 m were also mapped, and their height was measured using an inclinometer. Within the adjacent native area, five 20 m x 20 m quadrats were laid out centred on the nested quadrats, and the number of plants of each tree species was counted in each quadrat. All species nomenclature follows Harden (1990–1993).

Environmental data

A 100 cm^3 soil sample was taken from near the centre of each of the 19 quadrats, and removed to the laboratory for physical and chemical analysis. The soil depth throughout the denuded area was recorded by hammering a marked pole into the ground every 5 m along 46 transects running at right angles to the fence and 10 m apart (a total of 541 measurements).

In the laboratory, the oven-dried soil samples were analysed using the methods of Grimshaw (1989) for: m-eq cation exchange capacity by the sodium acetate method; % soil organic matter by loss on ignition at 650°C; % coarse sand (particles 0.5–2 mm diam.), % fine sand (0.1–0.5 mm diam.) and % silt and clay (<0.1 mm diam.) by the sieving method.

Data analysis

Species-centred principal components analysis (PCA) of the floristic data (ter Braak 1988) was used to analyse the pattern of variation in plant species composition among the quadrat samples. Two separate analyses were run, one using only the data for the 14 quadrats from the denuded area, and one using all 19 quadrats.

The effects of the soil characteristics on the plant species composition were analysed by redundancy analysis (RDA) (ter Braak 1988). This is a constrained ordination technique based on principal components analysis that, in a joint analysis of the two data sets (i.e. floristic and environmental), assesses the degree to which they show co-variation (ter Braak & Prentice 1989). That is, it seeks patterns among the quadrats that occur in both data sets, while ignoring patterns that are unique to either one of the data sets alone; this is thus a direct gradient analysis technique. Once again, two separate analyses were run, one using only the data for the 14 quadrats from the denuded area, and one using all 19 quadrats.

We also undertook a PCA analysis of our floristic data in conjunction with the data of Cambage (1923) and of Hannon & Evans (1963), using only the presence-absence data for each species with extra weighting for the twelve most abundant species. The data from the unpublished floristic lists was unsuitable for our analysis.

The average height and density for each of the tree species (those > 2 m high) were calculated for 33 homogeneous sub-areas within the denuded area, varying in size from 275 to 1,250 m^2. These data were then correlated with the average soil depth for these areas using Pearson product-moment correlation coefficients (Wilkinson 1987), significance being assessed at the $p=0.05$ level. The quadrat frequency data for each species were also correlated with the average quadrat soil depth using Pearson product-moment correlation coefficients.

The degree of spatial clustering of plants in the denuded area was investigated by comparing the frequency distribution of the replicate samples for each species to a normal distribution using Kolmogorov-Smirnov one-sample tests (Wilkinson 1987), significance being assessed at the p=0.001 level. The frequency data from the 14 quadrats were arcsin(x/7) transformed prior to analysis, because frequency data expressed as proportions are likely to approximate a binomial distribution if the plants are randomly distributed (Bonham 1989); and the tree density data for the 33 sub-areas were ln(x+1) transformed, since randomly-distributed density data are likely to approximate a Poisson distribution (Bonham 1989).

The pattern of abundance of each species between the denuded area and the adjacent native area was investigated using non-parametric Mann-Whitney U-tests of the quadrat data (Wilkinson 1987), significance being assessed at the p=0.05 level. It should, however, be remembered that about 4 out of these 82 results could have a probability value of 0.05 or less by chance alone. The density of each of the tree species in the denuded and adjacent areas were also compared using Mann-Whitney U-tests, based on the 33 sub-areas in the denuded area and the 5 tree quadrats in the adjacent area.

Results

In total, 108 species were encountered in this study (Appendix 1), 92 of them occurring in the denuded area (18 of which were found only along the disturbed strip next to the railway line) and 16 found only in the adjacent native area. Twelve of these species are not native to the area, but only one of them (*Cirsium vulgare*) occurs there outside of the railway strip.

The ordination of the quadrats from the denuded area shows no consistent spatial pattern of floristic composition within this area (Figure 2a), although the western-most quadrat of the line closest to the fence was distinctly different in plant species composition from the other quadrats. This result implies that the majority of species either did not show any particular spatial pattern or that they were not sufficiently abundant for our sampling to detect any patterns that may have existed. The analyses of spatial clustering indicate that at least 14 of the species are not randomly distributed within the denuded area: *Allocasuarina littoralis, Daviesia corymbosa, Entolasia stricta, Eucalyptus agglomerata, E. gummifera, E. sclerophylla, E. sieberi, Grevillea buxifolia, Hakea dactyloides, H. sericea, Kunzea ambigua, Patersonia glabrata, Petrophile sessilis,* and *Platysace linearifolia*. However, the ordination analysis suggests that most of these non-random distributions are not correlated with each other.

A total of 765 plants was found to be taller than 2 m, although 121 (16%) of these were on the steep embankment between the denuded area and the adjacent native area (see Figure 1), and these were excluded from further analysis. Five of the species represented were multi-stemmed shrub species with only a few plants taller than 2 m, while six other species were single-stemmed trees/shrubs with low abundance (*Banksia ericifolia, Banksia serrata, Exocarpos cuppressiformis, Leptospermum trinervium, Persoonia levis,* and *Xylomelum pyriforme*). The remaining seven species were more common

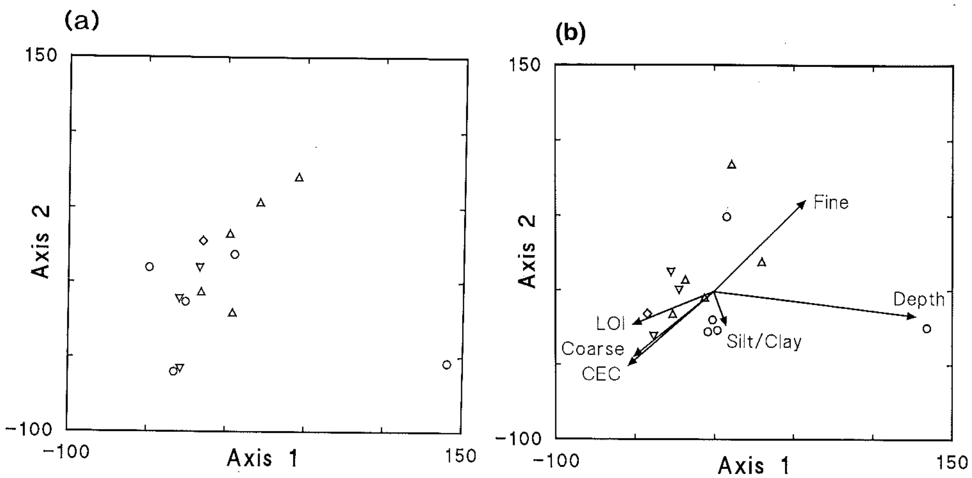

Fig. 2. Projection of the quadrats in the denuded area onto axes representing the first two components of **a**, the principal components analysis of the floristic data and **b**, the redundancy analysis of the floristic and soil variables data. (o) first, (◇) second, (▽) third and (Δ) fourth row of quadrats from the fence line; (Coarse) % coarse sand, (Fine) % fine sand, (Silt/Clay) % silt and clay, (LOI) % loss on ignition, (CEC) m-eq cation exchange capacity, (Depth) cm soil depth.

(Figure 3), with *Eucalyptus agglomerata*, *E. sieberi* and *E. sclerophylla* predominating. Of these species, the plants of *Allocasuarina littoralis* had three distinct height classes (Figure 3a), while those of *Hakea dactyloides* and *H. sericea* each had two height classes (Figure 3b); these height classes may represent distinct age classes. *Eucalyptus agglomerata*, *E. gummifera* and *E. sieberi* each had a small number of plants that were much taller then the others (Figure 3c–d), which may also represent a different age class.

The redundancy analysis of the quadrats from the denuded area shows a strong relationship between the pattern of floristic composition within the denuded area and the measured soil variables (Figure 2b), with the two axes shown accounting for 69% of the total sum of squares of the first two axes of the equivalent unconstrained ordination. In particular, soil depth is indicated as being an important characteristic, and the floristically-different quadrat (see above) was in an area with much deeper soil than were the other quadrats. About 16% of the denuded area was still without soil, and a further 36% of the area had soil less than 5 cm deep. However, there were many distinct pockets of deeper soil, particularly at the narrow ends of the segment and adjacent to the excavation embankment (Figure 4), and nearly 2% of the area had soil more than 40 cm deep (a maximum of 73 cm was recorded). For the tree species, the plants of *Eucalyptus sclerophylla* and *Hakea dactyloides* were denser in deeper soil, while the *Eucalyptus sieberi* and *Hakea dactyloides* plants were taller in deeper soil (Table 1); conversely, the plants of *Allocasuarina littoralis* were denser in shallower soil (Table 1). The more limited frequency data from the quadrats indicate that the abundance of a further nine species was positively related to the depth of the soil: *Acacia myrtifolia*, *A. suaveolens*, *Anisopogon avenaceus*, *Aristida ramosa*, *Cassinia quinquefaria*, *Cheilanthes tenuifolia*, *Danthonia tenuior*, *Lepidosperma laterale*, and *Mirbelia rubiifolia*.

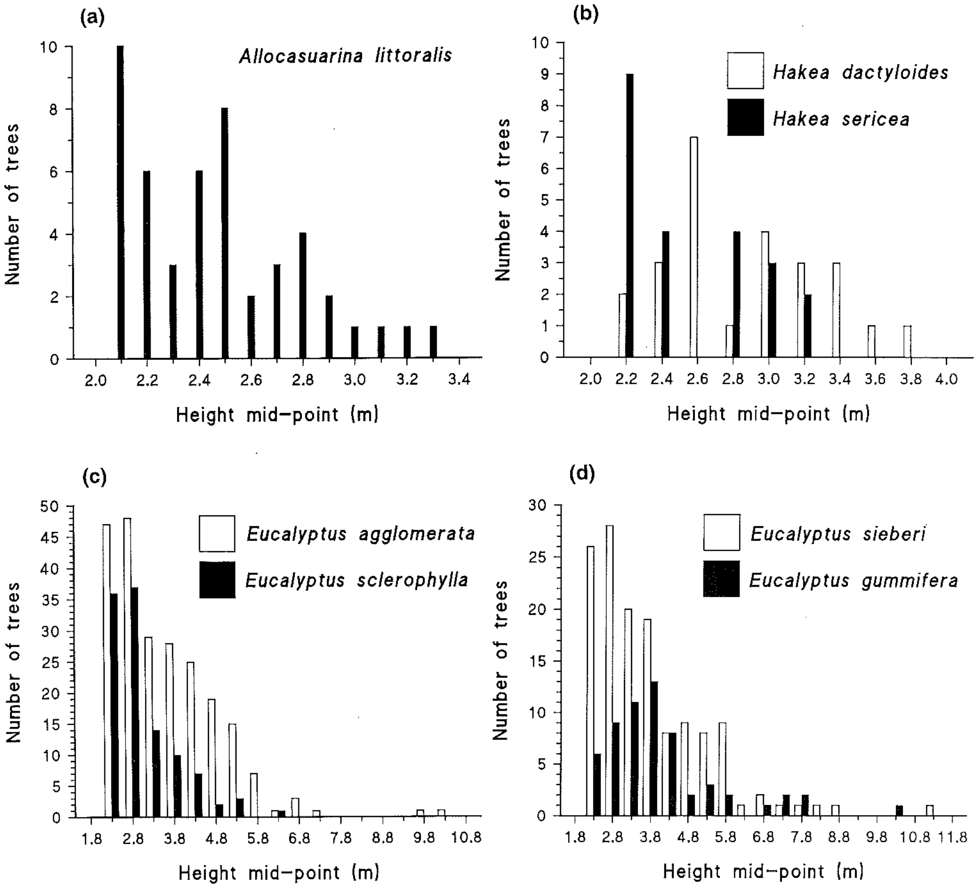

Fig. 3. Frequency of plant height classes for those species with more than ten plants >2.0 m tall in the denuded area.

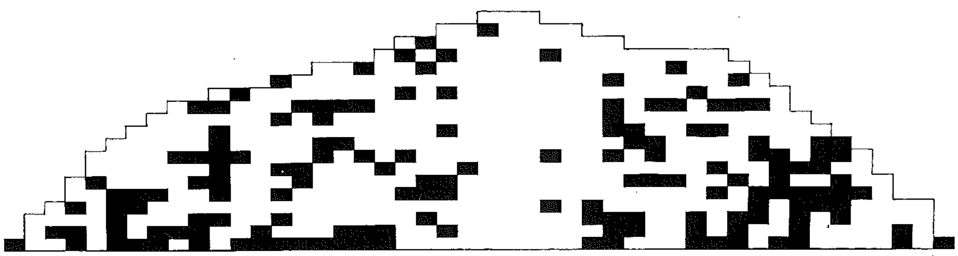

Fig. 4. Schematic representation of the spatial distribution of areas where the soil depth was greater than or equal to 10 cm (shaded) in the denuded area.

The ordination comparison of the quadrats from the denuded area and the adjacent native area shows a clear floristic distinction between the two data sets (Figure 5a). This distinction corresponds to differences in abundance of 32 shrub, herb and monocot species (39% of those in both data sets), with 25 species showing greater abundance in the native area and 7 showing lower abundance (Table 2). The ordination spacing of the quadrats from the native area is greater than for the quadrats from the denuded area (Figure 5a), indicating that there was more spatial heterogeneity in floristic composition in the native area. Furthermore, the species composition of the tree storey was dramatically different between the two areas (Table 3), with a significantly lower abundance of *Eucalyptus gummifera* and *E. sieberi* in the denuded area (total tree density in the denuded area being only 36% of that in the adjacent native area).

The redundancy analysis of the quadrats from the denuded area and the adjacent native area shows a strong relationship between the pattern of floristic composition between the areas and the measured soil variables (Figure 5b), with the two axes shown accounting for 63% of the total sum of squares of the first two axes of the equivalent unconstrained ordination. All of the soil characteristics are indicated as being important in the distinction between the quadrats from the two areas, with the denuded area having sandier soil with less organic matter and lower cation exchange capacity than the adjacent area. However, the soil characteristics do not account for the spatial heterogeneity in floristic composition of the quadrats within the native area.

The ordination comparison of the historical data shows a clear change in floristic composition of the denuded area through time (Figure 6). The average annual rate of change in species composition was apparently more than twice as great during the first 5 years of revegetation as it was during the next 39 years, which was in turn more than twice that during the the subsequent 27 years. Most of the change in composition has not made the denuded area floristically any more similar to the adjacent undisturbed area, and the slight increase in similarity that has occurred has mainly been during the most recent years.

Table 1. Correlation of soil depth with plant height and density for each of the tree species

Species	Correlation coefficient	
	Height	Density
Allocasuarina littoralis	0.33	–0.41 *
Hakea dactyloides	0.62 *	0.40 *
Hakea sericea	–0.37	0.08
Eucalyptus agglomerata	–0.05	0.12
Eucalyptus gummifera	–0.05	–0.02
Eucalyptus sclerophylla	0.01	0.55 *
Eucalyptus sieberi	0.48 *	0.03

* significant at $p<0.05$

Table 2. Average importance scores for species showing significant differences in abundance between the native and denuded areas, as determined by Mann-Whitney U-tests

Species	Native area	Denuded area
[Number of quadrats	5	14]
More abundant in native area		
Thysanotus tuberosus	6.4	0.1
Eragrostis brownii	6.2	1.9
Bossiaea obcordata	6.0	0.0
Cyathochaeta diandra	6.0	0.4
Isopogon anemonifolius	5.6	0.4
Hovea linearis	5.4	0.0
Lambertia formosa	4.4	0.1
Leptospermum trinervium	4.2	0.8
Gompholobium huegelii	3.8	0.0
Pimelea linifolia	3.8	1.4
Cassytha glabella	3.2	0.0
Boronia ledifolia	3.2	0.0
Lepyrodia scariosa	3.2	0.1
Phyllanthus hirtellus	2.8	0.0
Hakea dactyloides	2.8	0.3
Phyllota phylicoides	2.8	0.6
Dianella caerulea	2.6	0.4
Gompholobium grandiflorum	2.6	0.6
?*Callitriche stagnalis*	2.4	0.0
Dillwynia retorta	2.4	0.9
Xylomelum pyriforme	2.2	0.0
Lomatia silaifolia	1.8	0.0
Eriostemon australasius	1.8	0.0
Tetratheca thymifolia	1.8	0.0
Goodenia bellidifolia	1.6	0.0
More abundant in denuded area		
Kunzea ambigua	0.0	4.7
Daviesia corymbosa	1.2	4.3
Grevillea buxifolia	1.8	4.2
Entolasia stricta	1.6	4.0
Grevillea mucronulata	1.6	2.7
Leptomeria acida	0.0	2.2
Acacia terminalis	0.2	2.1

Table 3. Mean (± s.e.) eucalypt densities and percentage contribution to tree species composition

Species	Density (stems / hectare)		Composition (percent)	
	Native area	Denuded area	Native area	Denuded area
Eucalyptus agglomerata	115(10)	111(19)	20	44
Eucalyptus gummifera	235(55)	25(12) *	40	10
Eucalyptus sclerophylla	50 (8)	7(11)	9	19
Eucalyptus sieberi	180(20)	67(12) *	31	27

* significant at $p<0.05$ as determined by Mann-Whitney U-test

Discussion

Our study detected no consistent patterns of plant species composition on the denuded area, although many of the plants are not randomly distributed within this area, the plants occurring in clumps. The floristic composition of the area is thus, in general, relatively uniform. A number of the tree species show distinct height classes, which may be interpretable as age classes. If this is so, then there have been a number of episodes of successful colonisation of the denuded area. However, for at least some species (e.g. *Hakea dactyloides* and *Eucalyptus sieberi*) plant height is related to soil depth, and height classes may not accurately reflect plant age for these species.

Almost all of the exotic species in the disturbed area are confined to the narrow strip along the edge of the railway line, where many of them are quite common. The

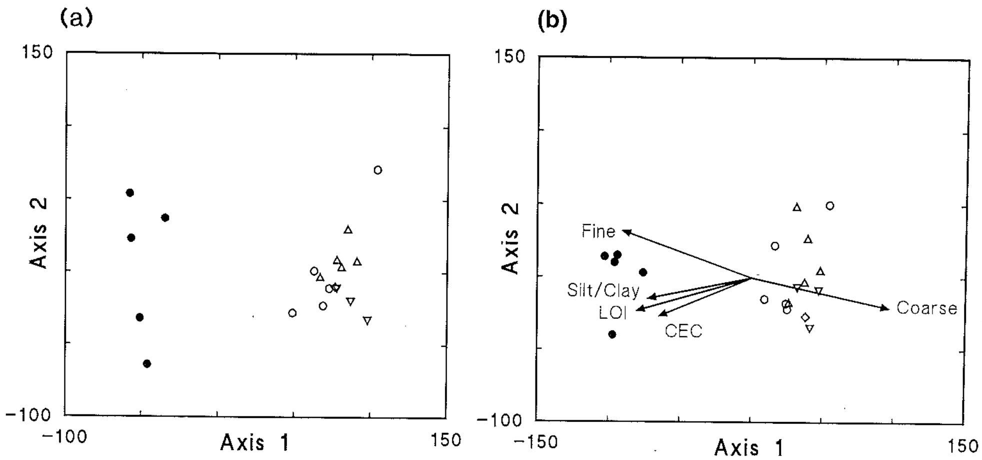

Fig. 5. Projection of the quadrats in the denuded and adjacent native areas onto axes representing the first two components of **a**, the principal components analysis of the floristic data and **b**, the redundancy analysis of the floristic and soil variables data. (o) first, (◇) second, (▽) third and (Δ) fourth row of quadrats from the fence line in the denuded area; (●) quadrats in the native area; (Coarse) % coarse sand, (Fine) % fine sand, (Silt/Clay) % silt and clay, (LOI) % loss on ignition, (CEC) m-eq cation exchange capacity.

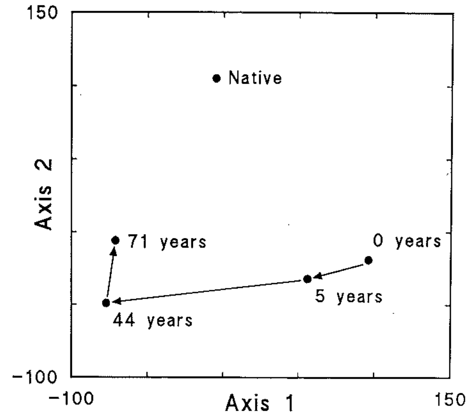

Fig. 6. Projection of the samples onto axes representing the first two components of the principal components analysis of the floristic composition, immediately after the area was denuded in 1918 (0 years), and from the studies of Cambage (5 years later), Hannon & Evans (44 years later) and this study (71 years later) in the denuded area, plus that of this study in the adjacent native area. The arrows indicate the presumed direction of change in species composition through time.

vehicular track thus forms a line of demarcation, dividing the excavated area into two distinct zones. The almost complete absence of exotics over most of the denuded area implies that this form of human disturbance is not amenable to the rapid establishment of non-native species (at least for sandstone bedrock), whereas at least 80 native species have successfully colonised the area. It is presumably the relatively thin and nutrient-poor nature of the soil that provides a suitable medium for the native species but not for the exotics (Hannon & Evans 1963).

The most significant environmental factor influencing the plant species within the denuded area is soil depth, with a number of species having increased abundance in areas with deeper soil. These species include trees, shrubs, herbs and grasses, their common denominator presumably being a lower drought tolerance (with a deeper root system?) than the other species. The only detected exception to this pattern was *Allocasuarina littoralis*, which was more abundant on the areas of shallow soil. This may indicate that this species is an early coloniser of the denuded area that competes less successfully with those species that are later colonisers. It may also be important that *A. littoralis* has nitrogen-fixing root nodules, thus surviving in areas of lower soil fertility.

Assuming that the adjacent native area has been the major seed source for those plants that have colonised the denuded area (passing trains are the only other likely source), then this must be the most relevant floristic comparison. There is a clear distinction between the plant species composition of the denuded area and the adjacent area, with 17% of the native species encountered not occurring in the denuded area and a further 16% showing a significantly lower abundance in this area. Once again, these species include trees, shrubs, herbs and grasses. The spatial heterogeneity of floristic composition was also much greater in the adjacent area than it was in the denuded area, presumably because of the greater species richness. Only seven native shrub and grass species had a greater abundance on the denuded area than in the adjacent area. The distinct differences in eucalypt species composition between the two areas and the much lower tree density in the denuded area may both be related to an inability to develop lignotubers in some of the species; and it may be instructive to test the possibility that *E. agglomerata* may not require a lignotuber for survival in the absence of fire.

The soil structure and fertility both showed significant differences between the native area and the denuded area, as presumably also did the soil depth (which could not be easily measured in the native area). It is therefore possible to hypothesise that it is these changes in the substrate that are the major determining factor as to which species have successfully colonised the denuded area. However, this hypothesis remains to be experimentally tested.

The most appropriate sampling technique for assessing the impact of human disturbance on the abundance of biological populations is a spatially and temporally replicated Before-After-Control-Impact design (Underwood 1991, 1992). This design was not possible in our study, because no samples were taken in the area before excavation in 1918 (allowing an assessment of the natural vegetation of the area), nor were detailed samples taken through time in the adjacent native area (to assess any temporal changes that may have occurred there as well). This certainly limits the possibilities for studying the primary successional sequence on the denuded area.

However, the limited analysis that we have undertaken indicates that there has been a large change in the floristic composition of the denuded area through time, that the rate of change has decreased in recent years, and that the change has not really made the denuded area floristically any more similar to the adjacent undisturbed area except possibly in recent decades. So, in spite of the relative success of the native plants in colonising the bare area, the revegetation to date can best be characterised as reclamation rather than restoration (using the terminology of Allen 1988). However, natural vegetation is rarely allowed to establish unaided after human disturbance, and this area provides an excellent opportunity for the continued study of natural rehabilitation.

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Appendix 1

Plant species found in the denuded area and the adjacent native area

(Nomenclature follows Harden [1990–1993])
* = introduced species
x = species found in the denuded area
† = species found only in the adjacent native area
r = species found mainly in the disturbed area next to the railway line

Botanical Name	Cambage (1923)	Hannon & Evans (1962)	Morrison et al. (1989)
PTERIDOPHYTES			
Adiantaceae			
Cheilanthes tenuifolia		x	x
Lindsaeaceae			
Lindsaea linearis		x	x
Schizaeaceae			
Schizaea bifida		x	x
ANGIOSPERMS–MONOCOTYLEDONS			
Anthericaceae			
Thysanotus tuberosus		x	x
Tricoryne simplex		x	x
Cyperaceae			
Cyathochaeta diandra		x	x
Lepidosperma laterale			x
Haemodoraceae			
Haemodorum planifolium	x	x	
Iridaceae			
Patersonia glabrata		x	x
Patersonia sericea	x	x	x
Juncaceae			
Juncus australis		x	x
Juncus subsecundus			x
Lomandraceae			
Lomandra cylindrica		x	x
Lomandra micrantha		x	x
Lomandra obliqua		x	x
Orchidaceae			
Caladenia carnea		x	
Calochilus robertsonii		x	x
Microtis unifolia		x	
Thelymitra ixioides		x	
Phormiaceae			
Dianella caerulea			x

Botanical Name	Cambage (1923)	Hannon & Evans (1962)	Morrison et al. (1989)
Poaceae			
Agrostis aemula	x		
Andropogon virginicus *		x	r
Anisopogon avenaceus		x	x
Aristida ramosa		x	x
Danthonia tenuior	x	x	x
Deyeuxia decipiens		x	x
Dichelachne rara		x	r
Entolasia stricta		x	x
Eragrostis brownii		x	x
Imperata cylindrica		x	r
Panicum effusum			r
Paspalum dilatatum *		x	r
Themeda australis			r
Vulpia myuros *	x		
Restionaceae			
Lepyrodia scariosa			x
Xanthorrhoeaceae			
Xanthorrhoea resinifera		†	†
ANGIOSPERMS–DICOTYLEDONS			
Apiaceae			
Platysace ericoides		x	x
Platysace linearifolia	x	x	x
Xanthosia pilosa		x	†
Asteraceae			
Cassinia aureonitens		x	
Cassinia quinquefaria			x
Cirsium vulgare *			x
Conyza albida *		x	r
Facelis retusa *		x	
Gnaphalium coarctatum *		x	
Helichrysum collinum		x	r
Hypochaeris radicata *	x	x	r
Olearia microphylla	x	x	x
Olearia sp.aff. *ramulosa*		x	
Olearia viscidula	x	x	
Ozothamnus diosmifolius		x	
Pseudo-gnaphalium luteo-album		x	
Senecio minimus		x	r
Vittadinia cuneata *		x	
Callitrichaceae			
Callitriche stagnalis			†
Campanulaceae			
Wahlenbergia gracilis		x	

Appendix 1 (cont.)

Botanical Name	Cambage (1923)	Hannon & Evans (1962)	Morrison et al. (1989)
Caryophyllaceae			
Silene gallica *			r
Casuarinaceae			
Allocasuarina littoralis	x	x	x
Dilleniaceae			
Hibbertia serpyllifolia		x	
Epacridaceae			
Brachyloma daphnoides		x	
Lissanthe sapida		†	†
Lissanthe strigosa		x	x
Monotoca scoparia		x	x
Euphorbiaceae			
Phyllanthus hirtellus			†
Poranthera corymbosa		†	
Poranthera ericifolia	x	†	†
Fabaceae subfam. Faboideae			
Bossiaea heterophylla			x
Bossiaea obcordata	x	x	†
Daviesia corymbosa	x	x	x
Daviesia ulicifolia		†	†
Dillwynia floribunda	x	x	x
Dillwynia parvifolia	x	x	x
Dillwynia retorta			x
Gompholobium grandiflorum	x	x	x
Gompholobium huegelii		x	†
Hovea linearis		†	x
Mirbelia rubiifolia	x	x	x
Phyllota phylicoides		x	x
Pultenaea villosa		x	
Sphaerolobium vimineum	x	x	
Trifolium arvense *		x	
Fabaceae subfam. Mimosoideae			
Acacia linifolia	x	x	x
Acacia myrtifolia	x	x	x
Acacia suaveolens	x	x	x,
Acacia terminalis		x	x
Acacia ulicifolia	x	x	x
Gentianaceae			
Centaurium erythraea *		x	

Botanical Name	Cambage (1923)	Hannon & Evans (1962)	Morrison et al. (1989)
Goodeniaceae			
Goodenia bellidifolia		x	x
Goodenia hederacea	x	x	x
Scaevola ramosissima		x	†
Lauraceae			
Cassytha glabella			†
Cassytha pubescens		x	x
Myrtaceae			
Eucalyptus agglomerata	x	x	x
Eucalyptus gummifera		x	x
Eucalyptus sclerophylla	x	x	x
Eucalyptus sieberi	x	x	x
Kunzea ambigua		x	x
Leptospermum trinervium	x	x	x
Leptospermum polygalifolia		x	r
Olacaceae			
Olax stricta		†	
Phytolaccaceae			
Phytolacca octandra *			r
Pittosporaceae			
Billardiera scandens			†
Plantaginaceae			
Plantago lanceolata *		x	r
Polygalaceae			
Comesperma defoliatum		x	
Comesperma ericinum	x	x	x
Polygonaceae			
Acetosella vulgaris *	x	x	r
Primulaceae			
Anagallis arvensis *		x	r
Proteaceae			
Banksia serrata		x	x
Banksia spinulosa	x	x	x
Conospermum longifolium		x	x
Grevillea mucronulata		x	x
Grevillea buxifolia	x	x	x
Hakea dactyloides		x	x
Hakea sericea		x	x

Appendix 1 (cont.)

Botanical Name	Cambage (1923)	Hannon & Evans (1962)	Morrison et al. (1989)
Isopogon anemonifolius		x	x
Isopogon anethifolius		x	
Lambertia formosa		x	x
Lomatia silaifolia		x	†
Persoonia lanceolata		x	x
Persoonia laurina		†	x
Persoonia levis		x	x
Persoonia linearis		†	
Petrophile pedunculata		x	x
Petrophile sessilis	x	x	x
Xylomelum pyriforme		†	x
Rubiaceae			
Pomax umbellata		x	x
Rutaceae			
Boronia ledifolia		†	†
Eriostemon australasius		†	†
Santalaceae			
Choretrum pauciflorum		†	
Exocarpos cupressiformis			x
Leptomeria acida		x	x
Scrophulariaceae			
Verbascum virgatum *			r
Thymelaeaceae			
Pimelea linifolia	x	x	x
Tremandraceae			
Tetratheca thymifolia		†	†
Verbenaceae			
Verbena bonariensis *			r
Violaceae			
Hybanthus monopetalus		†	
Total no. of species in the denuded area	**33**	**100**	**92**