THE VEGETATION AND FLORA OF THE COAL RIVER NATURE RESERVE

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(with four tables, four text-figures and an appendix)

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The Coal River Gorge Nature Reserve occupies most of a sandstone gorge and some adjacent hilltops in a dry part of Tasmania, the vegetation of which is poorly documented. Three dry sclerophyll and two wet sclerophyll plant communities were selected from a TWINSPAN analysis of higher plant species presence–absence data from 200 quadrats. The plant communities formed a continuum from heathy *Eucalyptus tenuiramis*, heathy *E. amygdalina* and grassy/shrubby *E. obliqua* dry sclerophyll communities to *E. obliqua–Pomaderris* and *E. obliqua–Olearia* wet sclerophyll communities. This continuum was related to the catena from the cliff top environments (altitude 350–450 m) to the base of the gorge (approximately 200 m). Soil moisture appeared to be a major variable related to the change in floristics and structure of the vegetation. The reserve, being small and downslope of developed land, has management problems related to nutrient drift, stock grazing and fire.

Key Words: flora, vegetation, dry sclerophyll forest, environmental relationships, conservation, Coal River Gorge, Tasmania.

INTRODUCTION

The characteristics and ecology of the main vegetation types in Tasmania have been well documented (e.g. Jackson 1968, Kirkpatrick 1977, Brown & Podger 1982, Ellis 1985, Kirkpatrick 1991). Studies on plant ecology of particular areas in Tasmania have tended to be concentrated in the west of the state and on the east coast. There are relatively few vegetation descriptions of areas within the dry southeastern–central region of the state (Hogg & Kirkpatrick 1974, Brown & Bayly-Stark 1979, Duncan & Harris 1983). The Coal River Gorge Nature Reserve is situated in the centre of this region. It incorporates a large part of the sandstone gorge of the Coal River 3 km northeast of Colebrook (fig. 1). It is one of the few secure reserves in this part of Tasmania. The documentation of the flora and plant communities of the reserve system is important in determining both gaps in its coverage and appropriate management.

In this paper we document the flora and vegetation of the Coal River Gorge Nature Reserve, analyse relationships between floristically defined communities and environmental conditions, and assess the conservation significance of our results.

THE STUDY AREA

An area of approximately 209 ha on the Coal River was proclaimed a State Reserve in December 1980, under the National Parks and Wildlife Act. Prior to reservation, the area was comprised of freehold land on the western side of the river and crown land, on which grazing leases were held, on the eastern side. From 1978 to 1980 the Lands Department acquired blocks or parts of blocks of this freehold land and terminated grazing leases on crown land which formed integral parts of the gorge. The freehold land acquired by the Lands Department was considered unlikely to be used for agricultural purposes.

The Reserve is located predominantly on sandstones and siltstones of lower Triassic age, except where it has cut into Upper Permian carbonaceous mudstones and siltstones at its southern end (Brighton map sheet 8312N, 1975; Oatlands map sheet 83138, 1975). The gorge has been incised to greater than 200 m along most of its length and is flanked by extremely steep cliffs. The reserve ranges in altitude from approximately 200 m to 450 m.

The mean annual rainfall at Colebrook is about 630 mm. It is relatively evenly distributed throughout the year (fig. 2). The mean daily temperatures in the Reserve are likely to be slightly lower than those given for Hobart Airport, the closest temperature station (fig. 3).

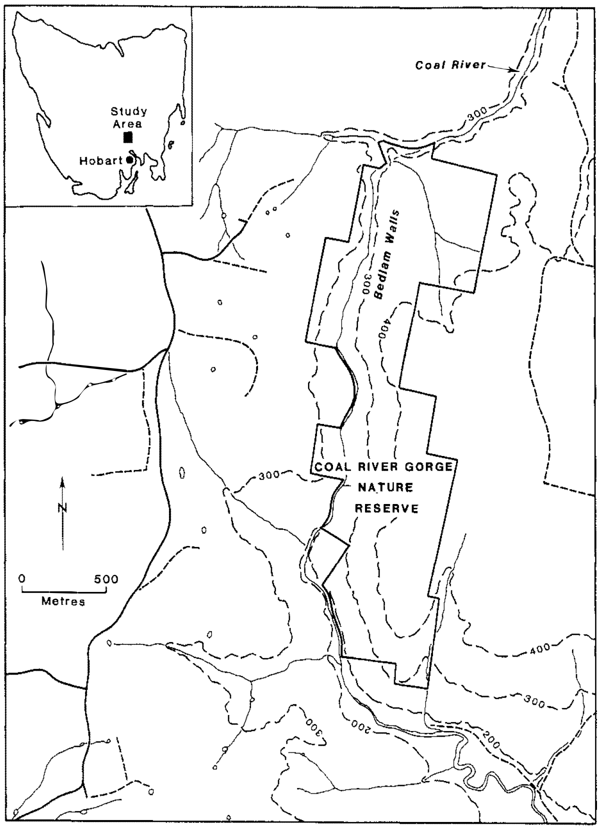

FIG. 1 — Location of the Coal River Gorge Nature Reserve in southeastern Tasmania.

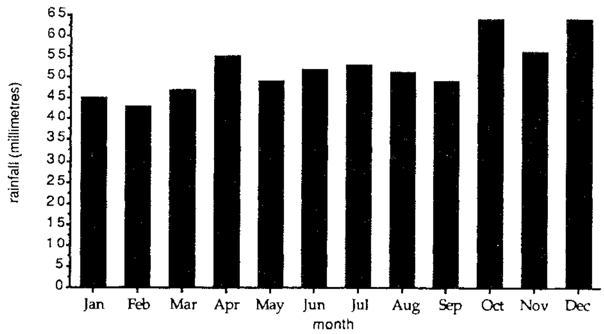

FIG. 2 — Mean monthly precipitation at Colebrook between 1974 and 1991. Source: Bureau of Meteorology, Hobart.

FIG. 3 — Mean daily temperatures from Hobart airport (approximately 50 km south of the Reserve) between 1944 and 1989. Source: Bureau of Meteorology, Hobart.

METHODS

One hundred 5 x 5 m quadrats were located in a stratified random manner. This size was considered to be sufficient to characterise the floristic composition of the vegetation, when combined with Bitterlich Wedge measurements (Mueller-Dombois & Ellenberg 1974) for the taller component. The reserve was divided into four environments: cliff top (48 quadrats); eastern slopes (18 quadrats); western slopes (18 quadrats); base of gorge (16 quadrats). A grid was placed over an aerial photograph of the Reserve and a random numbers table (Kmietowicz & Yannoulis 1976) was used to establish sampling locations. A further 100 quadrats were subjectively located in areas deemed not sufficiently covered by the stratified random location of sites (fig. 4). Most sites were in the reserve, but 11 sites were located on adjacent private property. Vegetation sampling took place from June to August 1992.

A list of the observed vascular plant species was compiled for each quadrat, and the dominant tree and shrub species were recorded. Species names follow Buchanan (1995). The percentage cover of trees, shrubs, ferns, grasses, leaf litter and rocks, and the amount of bare ground at each site were noted, and the average heights of trees, shrubs and ferns were estimated. The Bitterlich Wedge method was used to gain an estimate of basal area of trees at each quadrat. This method includes all plants with stems at eye height.

Within each quadrat the aspect (determined by compass), degree of slope (determined by clinometer), drainage and topographical position (cliff top, cliff, alluvial slopes or valley) were recorded. A soil sample was collected at each site.

The pH of each soil sample was determined by the use of a CSIRO test kit. Each sample was tested three times, and the average of these readings was taken to be the pH of the sample. The percentage weight loss on ignition was determined for each soil sample by the method outlined in Walter (1974). The weight loss on ignition provides an indication of the organic content of the soil.

Communities were selected from a sorted table of floristic quadrat data produced by the polythetic divisive classificatory programme TWINSPAN (Hill 1979). Mean values and standard deviations were used to describe the following characteristics of the plant communities and their environments: total species richness in quadrats; exotic species richness; endemic species richness; pH; and percentage weight loss on ignition.

Aerial photograph interpretation, field observation and the quadrat data were used to produce a vegetation map that indicates the distribution of floristic communities.

Depending on the characteristics of the data, chi-squared, Students t-test or the Mann-Whitney U test (Siegel 1956) was used to test hypotheses. A community dissimilarity matrix (Bray-Curtis) was calculated using species presence–absence data.

RESULTS AND DISCUSSION

The Flora

One hundred and eighty-five vascular plant taxa were recorded from the Reserve, including 21 trees, 13 ferns, 15 grasses, 44 shrubs, 70 herbs, 18 graminoids (Monocotyledonae not in the Poaceae), and four climbers/ scramblers (appendix). Twenty-nine exotic taxa and five Tasmanian endemic species formed part of this total. Species from the families Myrtaceae, Proteaceae, Asteraceae, Epacridaceae, Poaceae and Fabaceae dominate the flora. The list of species is incomplete, as collections took place at a time of the year when many taxa were not evident or identifiable to the species level.

Vegetation

Of the recognised vascular plant communities in Tasmania (Kirkpatrick *et al.* 1995), the Coal River Gorge Nature Reserve contains *Eucalyptus obliqua–Acacia dealbata–Olearia argophylla* wet sclerophyll forest; *E. obliqua–O. lirata–Pultenaea juniperina* wet sclerophyll forest; inland *Allocasuarina* low forest; heathy *E. amygdalina* forest on sandstone; heathy *E. tenuiramis* forest; shrubby *E. obliqua* forest; *Gonocarpus tetragynus–Stylidium graminifolium–Pteridium esculentum* heath.

The vegetation map differentiates three dry sclerophyll and two wet sclerophyll communities (fig. 4). These plant communities are described by their dominant species, faithful species, species richness, the occurrence of exotic and endemic species, vegetation physiognomy and tree basal areas. Their structural and floristic characteristics are summarised in tables 1 and 2.

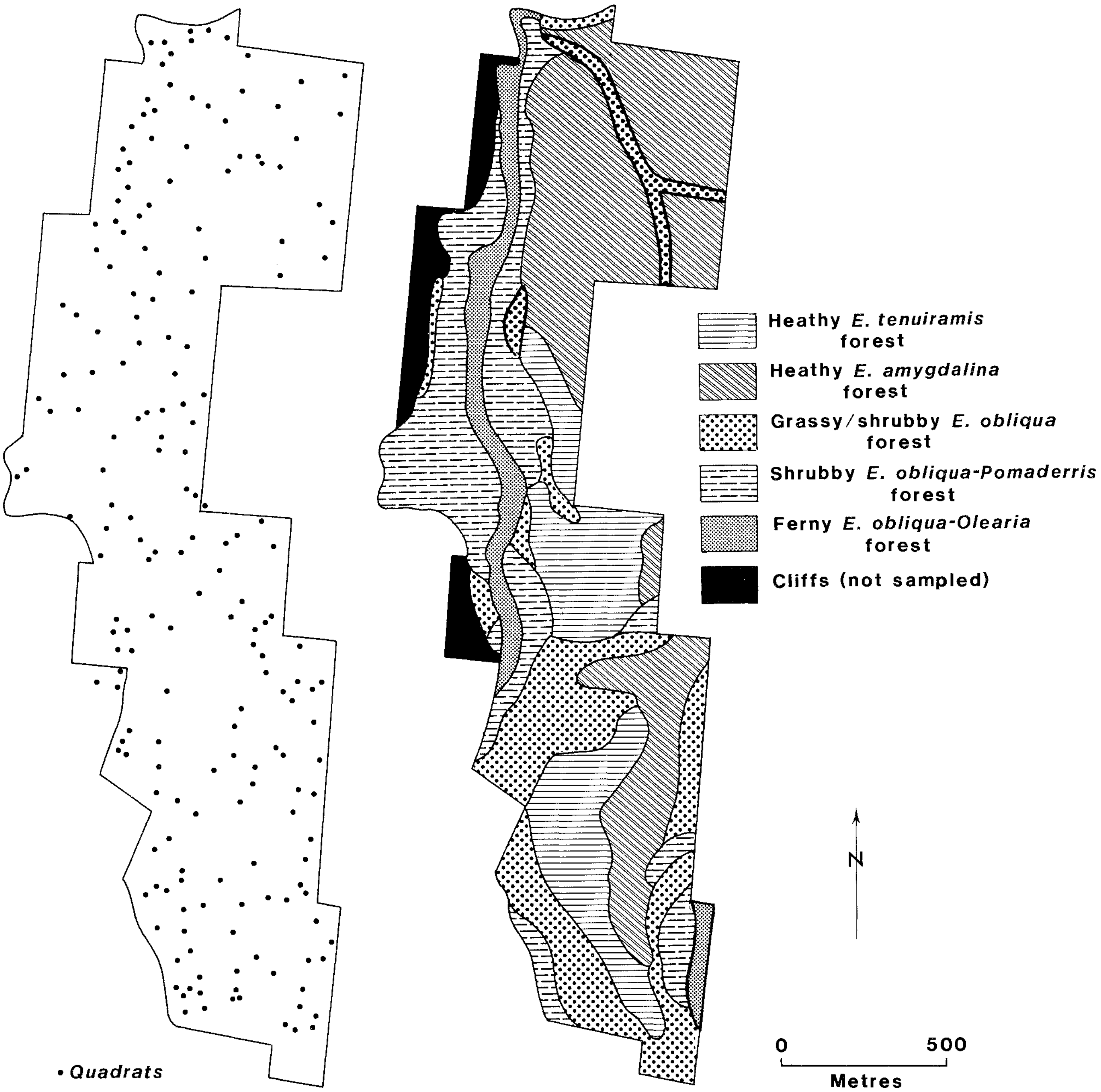

FIG. 4 — Location of sampling sites and plant communities in the Coal River Gorge Nature Reserve.

Group 000 — Heathy *Eucalyptus tenuiramis* forest
This dry sclerophyll community was found in 46 quadrats on the top of the eastern cliffs. It ranges in altitude from approximately 350 to 410 m. Mean tree height is 23 m (table 1). The total basal area is 30.37m^2/ha, and the dominant tree species are *E. tenuiramis* and *E. amygdalina* (table 1). The heathy understorey is variably dominated or co-dominated by the shrubs *Amperea xiphoclada, Aotus ericoides, Epacris impressa* and *Tetratheca labillardierei*, the herb *Stylidium graminifolium* and the fern *Pteridium esculentum*.

Species richness is relatively high (x = 11.50, SD = 2.71) with only a small proportion of the species (x = 1%) being exotics. This community contains few endemic species (x=1%), but these occur in over two-thirds of the quadrats. Species faithful to this group are the shrubs *Pimelea linifolia, Dillwynia sericea* and *Hibbertia riparia*, the herbs *Petrorhagia prolifera* and *Goodenia lanata*, and the parasitic climber *Cassytha pubescens*. The presence of *Amperea xiphoclada* and/or *Aotus ericoides* and the absence of *Pultenaea juniperina* generally discriminate the quadrats in this group from other quadrats. Among recognised communities the group best fits heathy *E. tenuiramis* forest (Kirkpatrick *et al.* 1995). However, there are also small areas of *Gonocarpus tetragynus–Stylidium graminifolium–Pteridium esculentum* heath (Kirkpatrick 1977) that floristically belong to this community.

Group 001 — Heathy *Eucalyptus amygdalina* forest
This dry sclerophyll community was found in 32 quadrats located on the relatively level sites above the eastern cliff and adjacent to the surrounding farmland. It ranges in altitude

TABLE 1
Structural and dominance variables for plant communities

	Community				
	000	001	01	10	11
No. of quadrats	46	28	65	44	17
Classification*	dsf	dsf	dsf	wsf	wsf
Mean % shrub cover	40	35	20	10	<5
Mean % fern cover	<5	<5	<5	10	30
Mean % grass cover	<5	20	25	5	<5
Mean % leaf litter	50	35	30	40	40
Total tree basal area (m^2/ha)	30	27	30	27	22
Eucalyptus tenuiramis basal area	15	5	3	<1	–
E. amygdalina basal area	9	12	3	<1	–
E. obliqua basal area	3	6	13	15	6
E. viminalis basal area	<1	1	3	2	<1
E. globulus basal area	<1	<1	1.5	<1	<1
Acacia dealbata basal area	–	–	1	1.5	2
A. melanoxylon basal area	–	–	<1	1	1.5
Pomaderris apetala basal area	–	–	–	2	5
Olearia argophylla basal area	–	–	–	<1	4
Dead tree basal area	3	4	4.5	5	5
Mean tree height (m)	23	24	23	30	32
Mean shrub height (m)	0.5	0.4	0.7	1.1	1.4
Mean fern height (m)	0.8	0.7	0.8	1.2	0.6
Mean % exotics in quadrats	1	4	10	7	1
% quadrats with exotics	9	36	57	30	6
Mean % endemics in quadrats	1	8	3	2	1
% quadrats with endemics	67	68	25	18	6
Mean tree species richness	2.30	2.00	1.85	2.32	2.29
Mean fern species richness	0.74	0.46	0.65	1.25	2.18
Mean shrub species richness	5.83	4.18	2.17	1.25	0.94
Mean grass species richness	0.50	1.82	1.97	0.82	0.12
Mean herb species richness	1.76	2.64	3.83	2.48	0.59
Mean graminoid species richness	0.33	0.79	0.69	0.20	0.00
Mean species richness	11.50	11.89	11.15	8.32	6.12
Standard deviation species richness	2.71	3.27	4.40	3.35	2.06

* dsf = dry sclerophyll forest, wsf = wet sclerophyll forest.

from approximately 350 to 450 m. Mean tree height is 24 m (table 1). The total basal area is 27.85m^2/ha, not significantly different to that of the heathy *E. tenuiramis* community. *E. amygdalina* is the dominant tree species, with *E. tenuiramis* and *E. obliqua* also being prominent (table 1). The heathy understorey is dominated by the shrubs *Epacris impressa, Pultenaea juniperina, Tetratheca labillardierei* and *Acacia dealbata,* the herbs *Gonocarpus tetragynus* and *Stylidium graminifolium,* and the grass *Poa* spp.

Species richness is relatively high (x = 11.89, SD = 3.27) with only a small proportion of species (x = 4%) being exotic. In comparison to community 000, the exotics occur in a relatively large proportion of quadrats (36%). The mean percentage of endemics in quadrats (x=8%) is higher than that found in any of the other communities.

Species faithful to this group are the shrub *Acrotriche serrulata,* the herbs *Gonocarpus humilis, Viola hederacea* and *Brachyscome aculeata,* and the graminoids *Schoenus apogon* and *Diplarrena moraea.* The quadrats in this community are generally separated from the other quadrats by the presence of *Pultenaea juniperina* and the absence of *Cassinia aculeata, Aotus ericoides, Amperea xiphoclada, Geranium* spp., *Oxalis perennans* and *Senecio linearifolius.* This community fits within the heathy *E. amygdalina* forest on sandstone of Duncan & Brown (1985).

Group 01 — Grassy/shrubby *Eucalyptus obliqua* forest

This dry sclerophyll community was found in 65 quadrats located mostly on the colluvial slopes around the southern end of the Reserve and within the drainage channel running across the northern end. Small pockets are also located along the cliffs within the gorge. It ranges in altitude from approximately 200 to 470 m. Tree height averages 23 m (table 1) *E. obliqua* is the dominant tree species, and *E. viminalis, E. tenuiramis* and *E. amygdalina* all occur as subdominants in fairly even proportions (table 1). The total basal area is 28.69m^2/ha, not significantly different to those of the heathy *E. tenuiramis* and heathy *E. amygdalina* communities. The understorey is dominated by the shrub *Cassinia aculeata,* the herb *Geranium* spp., the graminoid *Lomandra longifolia* and the grass *Poa* spp.

Species richness is relatively high (x = 11.15, SD = 4.40) and is very similar to that of the other dry sclerophyll communities (000 and 001). This community contains a greater proportion of exotic species (x = 10%) than any of the other groups and the exotic species are spread throughout a greater proportion of quadrats (57%). It contains relatively few endemics.

Species faithful to this group are the shrubs *Indigofera australis, Olearia viscosa, Rubus parvifolius* and *Lissanthe strigosa,* the herbs *Drosera* sp., *Geranium* spp., *Corybas* sp., *Carpobrotus rossii, Hypericum gramineum, Scleranthus biflorus, Craspedia glauca, Daucus carota, Lagenifera huegelii, Plantago varia* and *Leptorhynchos squamatus,* and the grass *Themeda triandra.* This community may generally be separated from the others by an occurrence of a combination of species, including at least one from *Cassinia aculeata, Geranium* spp., *Oxalis perennans* and *Plantago varia,* plus at least one from *Lomandra longifolia, Wahlenbergia* sp., *Aira caryophyllea* and *Exocarpos cupressiformis.* These species alone do not sufficiently discriminate this community from the others and, thus, the absences of *Amperea xiphoclada, Aotus ericoides, Bossiaea cinerea* and *Polystichum proliferum* are also an important feature.

From within community 01, three subcommunities may be differentiated. One is characterised by *Senecio linearifolius* and *Olearia lirata.* A second is characterised by *Exocarpos cupressiformis, Plantago varia* and *Aira caryophyllea.* A third is dominated by *Allocasuarina verticillata,* with an understorey of *Lomandra longifolia* and grass species. This latter subcommunity is confined to a small pocket on a north-west facing cliff at the southern end. It falls within the inland *Allocasuarina* low forest of Duncan & Brown (1985), whereas the remainder of community 01 falls within their shrubby *Eucalyptus obliqua* forest.

Group 10 — *Eucalyptus obliqua–Pomaderris apetala* wet sclerophyll forest

This wet sclerophyll community was found in 44 quadrats. These were located along the colluvial slopes within the gorge. It is situated predominantly below an altitude of 300 m. Mean tree height is 30 m, taller than the previous communities (table 1). The total tree basal area is 26.71 m^2/ha, slightly lower than that of the communities described previously. There are many standing dead trees (table 1). *E. obliqua, Pomaderris apetala* and *Acacia dealbata* are the dominant tree species, with the former constituting the tallest stratum. The understorey is dominated by the herb *Senecio linearifolius,* the fern *Pteridium esculentum* and the grass *Poa* spp.

Species richness is generally lower (x = 8.32, SD = 3.35) than that observed within the dry sclerophyll communities, and the proportion of exotic species in quadrats (x = 7%) is similar to that of communities 000 and 01. The proportion of endemic species is relatively low (x = 2%), and they occur in a relatively low proportion of quadrats (18%).

Species faithful to this community are the shrubs *Acacia verniciflua, Rosa rubiginosa* and *Olearia phlogopappa,* the herbs *Lagenifera stipitata, Ranunculus lappaceus, Plantago major* and *Senecio jacobaea,* the climber *Clematis aristata* and the graminoids *Lepidosperma laterale* and *Juncus pallidus.* The quadrats in this group are generally distinguished from other quadrats by the presences either of *Pomaderris apetala* and/or *Polystichum proliferum,* or of *Pteridium esculentum* and/or *Poa* spp., and an absence of *Dicksonia antarctica, Lomandra longifolia, Exocarpos cupressiformis, Aira caryophyllea* and *Plantago varia.* This community falls within the *Eucalyptus obliqua–Olearia lirata–Pultenaea juniperina* wet sclerophyll forest of Kirkpatrick *et al.* (1988).

Group 11 — *Eucalyptus obliqua–Olearia argophylla* wet sclerophyll forest

This wet sclerophyll community is located predominantly along the Coal River and occurred in 17 quadrats. It is situated below an altitude of 260 m. The mean tree height is 32 m, the tallest for any community (table 1). The total basal area (x = 22.60, SD = 8.04) for this community is considerably smaller than those previously observed. There are many standing dead trees (table 1). The dominant tree is *E. obliqua. Pomaderris apetala* and *Olearia argophylla* dominate the second stratum. The understorey is dominated by the shrub *Coprosma quadrifida* and the ferns *Dicksonia antarctica* and *Polystichum proliferum. Dicksonia antarctica* is the only species faithful to this group.

This community exhibits the lowest species richness (x = 6.12, SD = 2.06), a low proportion of exotic species (x = 1%) and a low proportion of endemics (1%). This group may generally be differentiated from the other communities by the presence of *Dicksonia antarctica* and/or at least two species from *Coprosma quadrifida, Olearia argophylla, Polystichum proliferum* and *Pomaderris apetala.* Also the absence of *Poa* spp., *Acaena novae-zelandiae, Viola hederacea* and *Geranium* spp. are diagnostic. This community falls within the *E. obliqua–Acacia dealbata–Olearia argophylla* wet sclerophyll forest of Kirkpatrick *et al.* (1988).

The dry sclerophyll communities from the Reserve are similar in structure and floristics to those described from sandstone elsewhere in the Southern Midlands and Derwent Valley (Hogg & Kirkpatrick 1974, Duncan & Brown 1985). The wet sclerophyll forest communities clearly belong to types widespread in Tasmania (Kirkpatrick *et al.* 1988).

Community Relationships

Vascular plant species richness exhibits a trend from high values in the dry sclerophyll communities to relatively low values in the wet sclerophyll communities (table 1). This trend is also shown in shrub species richness. Fern species richness shows the reverse trend. Tree species richness exhibits little variation, except that it declines slightly in the grassy/shrubby *E. obliqua* community, and graminoid richness is greatest in the heathy *E. amygdalina* and grassy/shrubby *Eucalyptus obliqua* communities. Grass and herb species richness are greatest in the grassy/shrubby *E. obliqua* community.

The heathy *E. tenuiramis* community and the ferny *E. obliqua–Olearia* community are the most dissimilar communities in the Reserve (table 3). The heathy *E. tenuiramis* and the heathy *E. amygdalina* communities are the most similar communities. The heathy *E. amygdalina* community and grassy/shrubby *E. obliqua* community are the next most similar groups. As could be expected, communities occurring in adjacency exhibit a higher degree of floristic similarity with each other than with those more distant, indicating an easily observable continuum of variation related to topographic position.

TABLE 2
Percentage frequency of species by group*

TWINSPAN group† Number of quadrats	000 46	001 28	01 65	10 44	11 17
Amperea xiphoclada	93.48	21.43	1.54	–	–
Epacris impressa	91.30	57.14	12.31	–	–
Aotus ericoides	86.96	17.86	–	–	–
Pteridium esculentum	73.91	46.43	61.54	68.18	17.65
Stylidium graminifolium	67.39	57.14	35.38	4.55	–
Banksia marginata	54.35	21.43	6.15	–	–
Eucalyptus tenuiramis	47.83	21.43	6.15	2.27	–
Bossiaea cinerea	34.78	7.14	–	–	–
Leucopogon collinus	32.61	7.14	–	–	–
Daviesia ulicifolia	28.26	25.00	6.15	–	–
Oxylobium ellipticum	23.91	14.29	1.54	–	–
Leucopogon ericoides	21.74	10.71	–	–	–
Astroloma pinifolium	21.74	10.71	–	–	–
Exocarpos cupressiformis	19.57	14.29	18.46	–	–
Leptospermum scoparium	17.39	3.57	3.08	–	–
Leucopogon virgatus	13.04	3.57	1.54	–	–
Poa spp.	36.96	85.71	80.00	54.55	5.88
Tetratheca labillardierei	78.26	85.71	10.77	–	–
Pultenaea juniperina	8.70	71.43	20.00	–	–
Acacia dealbata	39.13	64.29	60.00	31.82	23.53
Gonocarpus tetragynus	54.35	64.29	24.62	4.55	–
Eucalyptus amygdalina	23.91	50.00	4.62	–	–
Pterostylis spp.	28.26	50.00	16.92	2.27	–
Helichrysum scorpioides	–	32.14	7.69	–	–
Dianella tasmanica	28.26	32.14	15.38	–	–
Aira caryophyllea	4.35	28.57	26.15	–	–
Lomatia tinctoria	4.35	21.43	9.23	–	–
Pimelea humilis	10.87	17.86	12.31	–	–
Dichelachne spp.	–	17.86	1.54	–	–
Stipa spp.	–	14.29	10.77	2.27	–
Goodenia ovata	4.35	10.71	7.69	–	–
Acrotriche serrulata	–	10.71	–	–	–
Gnaphalium collinum	–	10.71	7.69	4.55	–
Cassinia aculeata	2.17	7.14	49.23	11.36	–
Lomandra longifolia	4.35	39.29	46.15	–	–
Geranium spp.	–	–	36.92	20.45	–
Eucalyptus obliqua	10.87	17.86	26.15	15.91	–
Viola hederacea	–	3.57	23.08	22.73	–
Wahlenbergia sp.	6.52	3.57	21.54	–	–
Plantago varia	–	–	21.54	–	–
Oxalis perennans	–	–	21.54	4.55	–
Danthonia spp.	6.52	3.57	13.85	–	–
Anthoxanthum odoratum	–	7.14	13.85	–	–
Senecio sp.	–	–	13.85	6.82	11.76
Hypochoeris radicata	–	3.57	12.31	6.82	–
Senecio lautus	–	–	12.31	–	–
Olearia lirata	–	–	23.08	59.09	23.53
Senecio linearifolius	–	–	29.23	47.73	11.76
Acaena novae–zelandiae	–	–	9.23	29.55	–
Hydrocotyle hirta	–	3.57	4.62	20.45	5.88
Acacia melanoxylon	6.52	–	6.15	15.91	5.88
Galium australe	–	–	6.15	11.36	5.88
Pimelea drupacea	–	–	–	11.36	5.88
Polystichum proliferum	–	–	–	40.91	94.12
Olearia argophylla	–	–	1.54	11.36	76.47
Pomaderris apetala	–	–	7.69	65.91	70.59
Coprosma quadrifida	–	–	3.08	18.18	58.82
Dicksonia antarctica	–	–	–	–	52.94
Hymenophyllum cupressiforme	–	–	–	2.27	17.65
Phymatosorus pustulatus	–	–	–	2.27	17.65
Stellaria flaccida	–	–	–	11.36	17.65
Australina pusilla	–	–	1.54	4.55	11.76
Blechnum wattsii	–	–	–	–	11.76
Dichondra repens	–	–	1.54	6.82	11.76
Pittosporum bicolor	–	–	–	2.27	11.76

• Showing those occurring in more than 10% of the quadrats in any one group.
† The species are ordered by their abundance within the group within which they are most abundant.

TABLE 3
Bray-Curtis dissimilarity matrix for plant communities

	000	001	01	10	11
000	0.0000	0.3983	0.6370	0.8073	0.9188
001	0.3983	0.0000	0.4878	0.7652	0.9105
01	0.6370	0.4878	0.0000	0.5462	0.8203
10	0.8073	0.7652	0.5462	0.0000	0.5809
11	0.9188	0.9105	0.8203	0.5809	0.0000

Environmental Relationships

The surface rock cover is greatest in the wet sclerophyll communities and least in the dry sclerophyll communities. The *E. obliqua–Olearia* community has a significantly higher rock cover than the *E. obliqua–Pomaderris* and dry sclerophyll communities, and the shrubby *E. obliqua–Pomaderris* forest has a higher cover than the dry sclerophyll forests. The grassy/shrubby *E. obliqua* community has a greater rock cover than the heathy *E. tenuiramis* and heathy *E. amygdalina* communities, which exhibit no significant difference between them (table 4).

The slope varies from steep cliffs to relatively level areas on top of the eastern cliff and on the valley floor. The grassy/shrubby *E. obliqua* and *E. obliqua–Pomaderris* communities occur on significantly steeper slopes than the other communities, and the heathy *E. tenuiramis* community occurs on significantly steeper slopes than the heathy *E. amygdalina* community.

The quadrats in the *E. obliqua–Olearia* wet sclerophyll community occur significantly more on southerly and easterly aspects than on other aspect classes. The quadrats in the *E. obliqua–Pomaderris* wet sclerophyll forest occur significantly more on southwesterly and northeasterly aspects. The quadrats in the dry sclerophyll communities occur significantly more on westerly and northerly aspects.

The soils in the heathy *E. tenuiramis* and heathy *E. amygdalina* communities are grey to brown, stony fine sandy loams. Depth ranges from 0.25 to 0.35 m. The soils of the grassy/shrubby *E. obliqua* and *E. obliqua–Pomaderris* communities are predominantly brown and are loam to fine sandy loams. Soil depth usually approximates 0.95 m. The soils of the *E. obliqua–Olearia* community are dark grey to dark brown-black and are fine loamy sands to silty clays with a moderate to low permeability. Soil depth usually approximates 1.4 m.

The heathy *E. tenuiramis* community is located within a significantly more acidic edaphic environment than any of the other communities, and the heathy *E. amygdalina* community occurs on more acidic soils than the grassy/shrubby *E. obliqua* community.

The only significant differences in the percentage weight loss on ignition involved the heathy *E. amygdalina* community, which had a lower value than both the *E. obliqua–Pomaderris* community and the *E. obliqua–Olearia* community.

The above data indicate that moisture availability is a major correlate of variation in the vegetation of the reserve. The water-holding capacity of the soils increases from the cliff top to the alluvial flats as a result of both increasing soil depth and a higher proportion of fine particles. Overland flow and ground water would tend to augment the amount of moisture available to be held in the soils of the lower slopes. Also, the magnitude of the impact of insolation on evapotranspiration generally decreases along the vegetation continuum from heathy *E. tenuiramis* dry sclerophyll forest to *E. obliqua–Olearia argophylla* wet sclerophyll forest as a result of variation in aspect and the effect of shading from the cliffs.

Tree height has been observed to be related to moisture status, with greater moisture availability being reflected in greater height (Kirkpatrick & Nunez 1980). The vegetation of the Reserve shows a trend in increasing eucalypt and shrub height from the dry sclerophyll communities to the wet sclerophyll communities (table 1), which coincides with the putative increase in soil moisture. The high proportion of dead trees in the wet sclerophyll forests might reflect a failure of downslope flow during the dry summers immediately preceding data collection (cf. Kirkpatrick & Marks 1985).

TABLE 4
Environmental variables for plant communities

Community	000	001	01	10	11
No. of quadrats	46	28	65	44	17
soil colour	dark grey	dark brown	dark brown	dark brown	black
soil depth (m)	0.25–0.35	0.25–0.35	0.95	0.95	1.40
Mean pH	5.0	5.7	6.0	6.2	6.0
Standard deviation pH	0.7	0.7	0.8	1.0	1.6
Mean % weight loss on ignition	9.6	7.8	10.3	10.8	12.4
Standard deviation weight loss on ignition	5.0	4.3	6.6	5.4	7.2
Mean % bare ground	30	15	20	20	20
Mean % rock cover	<5	<5	5	10	20
Mean degree ground slope	5	<5	20	16	5
Aspect*	2.5	2	2	3	4

* Aspect coded on ecological similarity as follows: 1 = NW (driest aspect); 2 = W, N; 3 = SW, NE; 4 = S, E; 5 = SE (wettest aspect).

Our limited data related to soil nutrient availability, pH and soil organic content, also indicates an increase from the cliff top to the alluvial flats. However, the magnitude of the differences is much less than with the attributes related to moisture availability. Both pH and organic content can be as much a function of the vegetation type as a cause of its differentiation. For example, the litter of *Pomaderris* is know to be rich in calcium, which would increase pH (Ashton 1976), and soil organic content is a partial function of vegetation productivity (Attiwill & Leeper 1987). Nevertheless, soils could be expected to be naturally more fertile on the lower slopes, as a result of downslope movement of nutrients through leaching and erosion over time, and because the rocks that tend to form cliff tops are among the more siliceous in a sedimentary series. Certainly, the transition from scleromorphic understoreys to those with substantial components of grasses and broad-leaved shrubs, as recorded in the Coal River Gorge, is typically associated with increasing nutrient status (e.g. Specht 1974).

The codirectionality of moisture and nutrient status makes it impossible to tease out their exact contributions to variation in the vegetation. These gradients may be reinforced by a feedback mechanism between environment, vegetation and litter characteristics and fire frequency, such that fire is least frequent in the valley flats and most frequent on the cliff tops. However, apart from the observation that fire has been more recent on the cliff top than in the valley, we have no data on this subject.

Conservation Significance and Management

With one exception the species and floristic communities identified in this study are considered to be well reserved (Kirkpatrick *et al.* 1995). The heathy *Eucalyptus tenuiramis* forest which was once widespread in the southern Midlands and Derwent Valley (Williams 1991) is that exception. The Coal River Gorge Nature Reserve is its sole security.

The nature of the Coal River Gorge poses a number of problems for management. Firstly, it does not occupy a complete catchment. It is situated mostly in a valley and as a result is subjected to runoff from the surrounding pastures on the hill tops. Secondly, it is long and narrow with a correspondingly high perimeter to area ratio. And thirdly, its relatively small size (209 ha) means that it is at risk from a single event, such as fire.

However, the Reserve is contiguous with other relatively undisturbed areas on private property. Much of this land is likely to remain unmodified due to its inappropriateness for agricultural or grazing purposes, but it is realistic to assume that clearance will continue on suitable land. There is a need to encourage the retention of this native bush surrounding the Reserve for a number of reasons. Firstly, it increases the effective size of the Reserve; and, secondly, it acts as a buffer zone between the Reserve and farmed lands.

Exotic species invasion into the Reserve occurs from surrounding private property; and from water-borne seeds carried by the Coal River. Although exotic species, such as blackberries, were observed growing adjacent to the river, there is no evidence that they are invading the surrounding wet sclerophyll environment. The majority of exotic species invasion is occurring along the interface between the Reserve and farmland.

We recommend that the presence of willow trees (*Salix alba*) in the Coal River at the southern end of the Reserve be monitored to ensure that they are not being dispersed upstream. The majority of exotic species observed in the Reserve are herbaceous and do not seem to threaten the native species.

The southern end of the Reserve is subjected to grazing by sheep and cattle from adjacent private property. The cliff line and adequate fencing on most Reserve boundaries appear to prevent grazing from occurring in rhe bulk of the Reserve. We recommend that grazing be totally excluded from the Reserve by the improvement of the boundary fence.

Fire is an integral part of the ecology of the plant communities in the Reserve. The amount of dead wood resulting from extensive tree dieback in both the dry and wet sclerophyll communities may increase the severity of fire if it occurs. Fire sensitive species, such as *Olearia argophylla,* which gain some protection from fire in the moist gully location, may have their protection decreased by the dead wood which acts as a source of fuel.

The control of fire regimes in dry sclerophyll vegetation is important in management for conservation. For example, fire regimes of less than ten years are known to reduce species richness in most sedgey and heathy dry sclerophyll communities and a regime of less than 20–25 years reduces richness in shrubby communities (Williams 1991). Conversely, richness also declines in these dry sclerophyll communities if the fire-free period is too great.

We recommend that fire be used as a management tool in the dry sclerophyll vegetation if the fire free period becomes great enough to put species richness at risk. Fire should not normally be used as a management tool in the wet sclerophyll vegetation as the need for it is so infrequent and accidental fires are likely to provide for that need.

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APPENDIX
Higher plant species observed in the Coal River Gorge Nature Reserve

Trees
Acacia dealbata
A. melanoxylon
Allocasuarina verticillata
+*Asterotrichion discolor*
Banksia marginata
Bedfordia salicina
Bursaria spinosa
+*Eucalyptus amygdalina*
E. brookeriana
E. globulus
E. obliqua
E. ovata
+*E. tenuiramis*
E. viminalis
Exocarpos cupressiformis
Olearia argophylla
**Pinus radiata*
Pittosporum bicolor
Pomaderris apetala
P. elliptica
**Salix alba*

Shrubs
Acacia gunnii
A. verniciflua
Acrotriche serrulata
Amperea xiphoclada
Aotus ericoides
Astroloma humifusum
A. pinifolium
Bossiaea cinerea
Cassinia aculeata
Coprosma hirtella
C. quadrifida
Cyathodes glauca
Daviesia latifolia
D. ulicifolia
Dillwynia sericea
Epacris impressa
Goodenia ovata
Ozothamnus ferrugineus
O. obcordatum
O. thyrsoideus
Hibbertia riparia
Indigofera australis
+*Leptospermum glaucescens*
L. lanigerum
L. scoparium
Leucopogon collinus
L. ericoides
L. virgatus
Lissanthe strigosa
+ *Lomatia tinctoria*
Olearia lirata
O. phlogopappa
O. ramulosa
O. viscosa
Oxylobium ellipticum
Persoonia juniperina
Pimelea drupacea
P. humilis
P. linifolia
Pomaderris pilifera
Pultenaea juniperina
* *Rosa rubiginosa*
Tetratheca labillardierei
Zieria arborescens

Climbers/Scramblers
Cassytha pubescens
Clematis aristata
* *Rubus fruticosus*
R. parvifolius

Herbs
Acaena novae-zelandiae
A. ovina
* *Acetosella vulgaris*
Ajuga australis
* *Anagallis arvensis*
Australina pusilla
Brachyscome aculeata
Cardamine sp.
Carpobrotus rossii
**Centaurium erythraea*
* *Centranthus ruber*
Chrysocephalum apiculatum
C. semipapposum
* *Cirsium arvense*
* *C. vulgare*
**Conium maculatum*
Craspedia glauca
Crassula sieberiana
Cynoglossum australe
Myosotis exarrhena
* *Daucus carota*
Dichondra repens
Drosera sp.
Epilobium sp.
Galium australe
* *Geranium dissectum*
G. spp.
Gnaphalium collinum
Gonocarpus humilis
G. tetragynus
G. teucrioides
Goodenia lanata
Helichrysum scorpioides
Hydrocotyle hirta
Hypericum gramineum
* *Hypochoeris radicata*
Lagenifera huegelii
L. stipitata
* *Leontodon taraxacoides*
Leptorhynchos squamatus
Oxalis perennans
Pelargonium australe
* *Petrorhagia prolifera*
* *Plantago major*
P. varia
Poranthera microphylla
Ranunculus lappaceus
R. pumilio
Rorippa dictyosperma
Scleranthus biflorus
* *Senecio jacobaea*
S. lautus
S. linearifolius
S. sp.
* *Sonchus asper*
* *S. oleraceus*
* *Spergularia rubra*
Stackhousia monogyna
Stellaria flaccida
* *S. graminea*
* *S. media*
S. pungens
Stylidium graminifolium
* *Trifolium sp.*
Urtica incisa
* *Verbascum thapsus*
Veronica calycina
Viola hederacea
Wahlenbergia quadrifida
W. sp.

Grasses
Agrostis spp.
* *Aira caryophyllea*
* *Anthoxanthum odoratum*
* *Cynosurus echinatus*
Danthonia spp.
Deyeuxia quadriseta
Dichelachne spp.
Ehrharta stipoides
Elymus scabrus
* *Holcus lanatus*
Poa labillardierei
P. rodwayi
P. sieberiana
Stipa spp.
Themeda triandra

Graminoids
Bulbine bulbosa
Carex appressa
C. sp.
Chiloglottis reflexa
Corybas sp.
Dianella revoluta
D. tasmanica
Diplarrena moraea
Isolepis cernua
Juncus pallidus
J. pauciflorus
Lepidosperma laterale
Lomandra longifolia
Luzula sp.
Pterostylis spp.
Schoenus apogon
Tetraria capillaris
Triglochin procera

Ferns
Adiantum aethiopicum
Asplenium flabellifolium
A. terrestre
Blechnum nudum
B. penna-marina
B. wattsii
Dicksonia antarctica
Hymenophyllum cupressiforme
Pellaea falcata
Phymatosorus pustulatus
Pleurosorus rutifolius
Polystichum proliferum
Pteridium esculentum

* introduced species
\+ Tasmanian endemic species