# Vegetation associated with *Wollemia nobilis* (Araucariaceae)

*John Benson and Chris Allen*

Plant Sciences, Royal Botanic Gardens and Domain Trust, Sydney, NSW 2000, AUSTRALIA.
Corresponding author, email: john.benson@rbgsyd.nsw.gov.au

***Abstract:*** *Wollemia nobilis* Jones et al. (Wollemi Pine) is restricted to four sites growing in warm temperate rainforest typical of the canyons in the Blue Mountains and Wollemi National Parks. 88 vascular plant species were recorded from four sites. The tree canopy at all sites is dominated by *Wollemia nobilis*, *Ceratopetalum apetalum*, *Doryphora sassafras* and *Acmena smithii*. A large number of fern and vine species dominate the forest floor. Site 1 contains more species than the other sites, possibly due to its diversity of topographic features. Similarity analysis indicates that sites 2 and 3 are the most similar and sites 1 and 4 are least similar in floristic composition. 54% of plant species were recorded at one site only. *Ceratopetalum apetalum*, *Blechnum cartilagineum* and *Wollemia nobilis* were found to contribute most to the similarity between sites.

***Cunninghamia*** **(2007) 10(2): 255– 262**

## Introduction

The discovery of the *Wollemia nobilis* Jones et al. (Wollemi Pine) in 1994 in a canyon in the Wollemi National Park west of Sydney, New South Wales (Figure 1) resulted in the description of a new genus in the southern conifer family Araucariaceae. Since then, about 40 publications on many aspects of the conifer have been published (listed on the Botanic Gardens Trust, Sydney web site at www.rbgsyd.nsw.gov.au). This paper documents the associated vascular plant species at the four known sites of *Wollemia nobilis*.

## Habitat

*Wollemia nobilis* is a rare species with 83 plants so far recorded in the wild (J. Benson unpublished data). These are distributed over four sites. However, *Wollemia nobilis* has no detectable genetic variation (Peakall et al. 2003) and it is difficult in the field to determine clonal (ramets) from individuals that originated from seedlings (genets).

All sites of *Wollemia nobilis* occur at the base of Triassic Narrabeen Sandstone cliffs on shallow, sandy loam soils that are acidic with a pH between 3 and 4 (Department of Environment and Conservation NSW 2007). Most of the *Wollemia* trees grow on steep slopes from ranging from 30–80 degrees and on ledges situated 5–20 m above the canyon floor. While some *Wollemia nobilis* trees and seedlings grow on high ledges on these cliffs and mix with typical Blue Mountains dry sclerophyll vegetation, most *Wollemia* trees grow in warm temperate rainforest that dominates the lower slopes and lower ledges. This type of rainforest is common in canyons and gullies in the Blue Mountains and Wollemi National Parks (Floyd 1990). The canyons retain a relatively high humidity compared to the slopes above and the evaporation rates are limited by shade and protection from desiccating winds. Most of the *Wollemia* trees grow within 20 m of streams and their roots often extend down slope into the canyon floor where water is available all year round. This attribute may explain how *Wollemia nobilis* has survived drought.

The canyons are protected from most wildfires but there is evidence that many if not most *Wollemia* trees have been burnt at all sites. Too intense or too frequent fire may threaten the survival of *Wollemia nobilis* by killing trees and seedlings. However, the ability of the species to grow suckers from basal buds allows it to re-sprout after disturbance including rock falls and fire. Periodic disturbance, perhaps on a small scale, is probably required to produce canopy gaps that allow more light to reach the forest floor thereby providing the opportunity for seedlings to mature and grow into adult plants (T. Auld & J. Benson pers. comm.).

## Methods

Vascular plant species were recorded from the four known groves of *Wollemia nobilis* in 2001 and 2002. Plant species were recorded from the area within the boundary of the canopy dominance of *Wollemia nobilis*. Cover scores were assigned to each species present based on a modified Braun-Blanque scale (Poore 1955). Floristic and vegetation structural data was entered into the NSW Department of Environment and Conservation MS Access Floristic Site Survey YETI Database. Physical attributes of the sites were also recorded but the latitude and longitude of the sites were not recorded or data-based in order to maintain the confidentiality of the locations.

The sites were not uniform in size so the interpretation of the analyses of the data needs to take this into account. Site 1 covers 100 m x 100 m; site 2, 150 x 30 m; site 3, 20 x 20 m; and site 4, 200 m x 30 m. These areas reflect the total area of canopy cover dominance of the *Wollemia nobilis* in the wild, i.e. about 2.2 hectares.

The site floristic data were analysed using Primer V4.0 and transferred to MS Excel for graphing and summary presentation. Non-metric multi-dimensional scaling (MDS) ordination using Bray Curtis similarities from normalised (double root-transformed) species cover rating was applied to the species data (Sokal & Rohlf 1995). Plant species presence was determined for each of the sites and was expressed in a plant species presence biplot in a MDS ordination on Bray-Curtis similarities. Plant species coverage of each study site was also recorded and given a score of 1–6, in which 1=0.01–1%, 2=1–5%, 3=5–25%, 4 =25–50% and 5=50–75% and 6=>75%. To produce similarities based on % coverage class, calculations were repeated for each species using the maximum and minimum possible percentage within each class and the resultant points on the biplot joined to produce a closed curve delimiting the possible range of similarities. This gave a range of possible plant species coverages for each site. Results were depicted on the same biplot, expressed as an MDS ordination on Bray-Curtis similarities, although analysed separately to the presence/absence data.

## Results

*Description*

88 vascular plant species were recorded in the 2.2 hectares of warm temperate rainforest that contain the four sites of *Wollemia nobilis* (Table 1). Ferns, vines, trees and shrubs were the main growth forms with a low number of grasses, forbs and sedges (Table 2).

All sites contain a closed canopy vegetation structure with a sparse layer of shrubs or young trees and a dense layer of ferns. Vines are a common feature at all sites. A tree stratum averaging 20–30 m high is dominated by the rainforest trees *Wollemia nobilis* (Wollemi Pine), *Ceratopetalum apetalum* (Coachwood), *Doryphora sassafras* (Sassafras) and *Acmena smithii* (Lilly Pilly). *Backhousia myrtifolia* (Grey Myrtle) was recorded only at site 1. Some *Wollemia nobilis* stems are over 30 m high and emerge above the rainforest canopy.

*Eucalyptus* occur in low numbers including *Eucalyptus piperita* (Sydney Peppermint) at sites 1 and 3 and *Eucalyptus punctata* (Grey Gum) at site 2. *Angophora costata* occurs just outside the site 1 *Wollemia* stand. Small rainforest trees or shrubs include *Ficus coronata* (Sandpaper Fig), *Elaeocarpus reticulatus* (Blueberry Ash), *Notelaea longifolia* (Mock Olive) and *Eupomatia laurina* (Bolwarra). *Dicksonia antarctica* (Soft Treefern) is common at all sites while *Cyathea australis* (Rough Treefern) was recorded only at site 4. On the upper slope margins of *Wollemia* extent, dry sclerophyll shrubs including the small trees/shrubs *Allocasuarina torulosa*, *Leptospermum trinervium*, *Nematolepis squamea* subsp. *squamea* and *Persoonia linearis* mix with rainforest species. A few species of heath-shrub in the family Epacridaceae grow on ledges or in cracks in the sandstone cliffs – these include *Dracophyllum secundum* and *Rupicola ciliata*.

A feature of the rainforest is the abundance of vines. Some vines such as *Pandorea pandorana*, *Morinda jasminoides* and *Parsonsia purpurescens* climb to the canopy of the forest. Others, such as *Smilax glyciphylla* and *Rubus* spp. are bushy scramblers on the forest floor.

21 species of ferns were recorded. *Sticherus flabellatus* var. *flabellatus* dominates the ground cover at site 1 and is a co-dominant at the other sites. *Blechnum cartilagineum* dominates the forest floor at all sites but especially at site 3 and on the upper slopes of site 4 that are drier and more exposed than most of the habitat at site 1 and site 2. *Lastreopsis acuminata* is common at all sites but absent from the driest site (site 3). *Todea barbara* is common on the banks of the streams. *Blechnum patersonii*, *Blechnum wattsii* and *Leptopteris fraseri* occur on moister, lower slopes, in sandstone overhangs or along streams on the canyon floors where light levels are low. Other fern species include *Asplenium flabellifolium*, *Pellaea falcata* var. *nana* and *Calochlaena dubia*.

Few grasses, sedges, rushes or forbs grow under the dense fern ground cover. *Lomandra filiformis* subsp. *filiformis* is commonly found growing on rock ledges. Lithophytes include the orchid species *Liparis reflexa* and *Dendrobium teretifolium* that grow on cliffs. Epiphytes include the fern *Tmesipteris parva* growing on the trunks of treeferns, the mistletoe *Muellerina celastroides* growing in the canopy of *Ceratopetalum apetalum* trees, and *Sarchochilus falcatus* (Orange Blossum Orchid) growing on the upper branches of rainforest trees. No vascular epiphytes have been recorded growing on *Wollemia nobilis*.

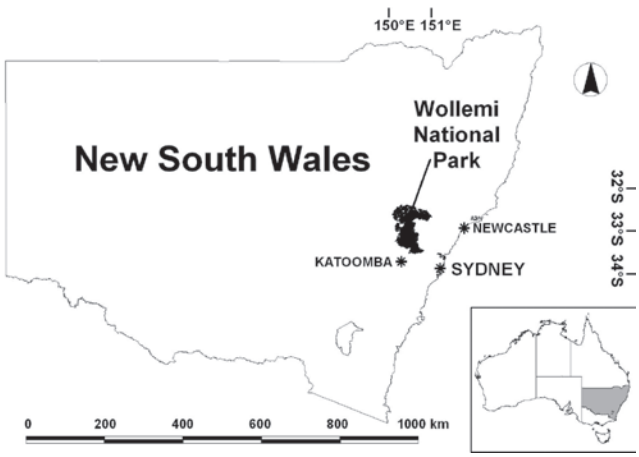


**Fig. 1**. Location of Wollemi National Park in New South Wales, Australia

**Fig. 2.** The habitat of Wollemia nobilis at site 1 showing warm temperate rainforest dominated by Ceratopetalum apetalum (Coachwood) and Doryphora sassafras (Sassafras) with a dense ground cover of ferns. Photograph Jaime Plaza.

**Fig. 3.** Oblique aerial photograph of the site 1 of Wollemia nobilis showing the canyon environment, sandstone cliffs, rainforest habitat with some Eucalyptus present. Photograph John Benson.

**Table 1. Cover ratings of vascular plant species recorded at *Wollemia nobilis* sites.**

Growth form definitions are modified from Walker & Hopkins (1990). Cover ratings per site 1 = <1%, 2 = 1–5%, 3 = 5–25%, 4 = 25–50%, 5 = 50–75%, 6 = >75%

| Species (family) | Growth form | Site 1 | Site 2 | Site 3 | Site 4 |
|---|---|---|---|---|---|
| *Acacia longifolia* (Fabaceae-Mimosoideae) | Shrub | - | 1 | - | - |
| *Acmena smithii* (Myrtaceae) | Tree | 4 | 2 | 2 | 3 |
| *Adiantum formosum* (Adiantaceae) | Fern | 1 | - | - | - |
| *Adiantum hispidulum* (Adiantaceae | Fern | - | 1 | - | - |
| *Allocasuarina torulosa* (Casuarinaceae) | Tree | 1 | 1 | 1 | - |
| *Amperea xiphoclada* (Euphorbiaceae) | Shrub | 1 | - | - | - |
| *Aphanopetalum resinosum* (Cunoniaceae) | Vine | 1 | - | - | - |
| *Asplenium flabellatum* Adiantaceae | Fern | 1 | - | - | - |
| *Asplenium flabellifolium* (Aspleniaceae) | Fern | 1 | 1 | 1 | 1 |
| *Backhousia myrtifolia* (Myrtaceae) | Tree | 2 | - | - | - |
| *Blechnum cartilagineum* (Blechnaceae) | Fern | 3 | 3 | 4 | 4 |
| *Blechnum nudum* (Blechnaceae) | Fern | 2 | - | - | - |
| *Blechnum patersonii* (Blechnaceae) | Fern | 1 | 3 | 1 | 1 |
| *Blechnum penna-marina* subsp. *alpina* (Blechnaceae) | Fern | - | - | 1 | - |
| *Blechnum wattsii* (Blechnaceae) | Fern | 1 | 1 | 1 | - |
| *Callicoma serratifolia* (Cunoniaceae) | Tree | 1 | - | - | - |
| *Calochlaena dubia* (Dicksoniaceae) | Fern | - | - | 1 | 3 |
| *Cephalaralia cephalobotrys* (Araliaceae) | Vine | 1 | - | - | - |
| *Ceratopetalum apetalum* (Cunoniaceae) | Tree | 5 | 4 | 5 | 4 |
| *Cissus hypoglauca* (Vitaceae) | Vine | - | 1 | - | - |
| *Clematis glycinoides* (Ranunculaceae) | Forb | 1 | - | 1 | - |
| *Cyathea australis* (Cyatheaceae) | Tree-fern | - | - | - | 1 |
| *Dendrobium teretifolium* (Orchidaceae) | Lithophyte | 1 | 1 | - | - |
| *Dianella caerulea* (Phormiaceae) | Forb | - | 1 | - | 1 |
| *Dicksonia antarctica* (Dicksoniaceae) | Tree-fern | 3 | 2 | 3 | 2 |
| *Dillwynia elegans* (Fabaceae-Faboideae) | Shrub | 1 | - | - | - |
| *Diplazium australe* (Athyriaceae | Fern | 1 | - | - | - |
| *Doodia aspera* (Blechnaceae) | Fern | 3 | - | - | - |
| *Doryphora sassafras* (Monimiaceae) | Tree | 4 | 3 | 1 | 2 |
| *Dracophyllum secundum* (Epacridaceae) | Heath-Shrub | 2 | 2 | 1 | 1 |
| *Elaeocarpus reticulates* (Elaeocarpaceae) | Tree | 1 | 1 | 1 | 1 |
| *Entolasia stricta* (Poaceae) | Tussock grass | - | - | 1 | - |
| *Eucalyptus piperita* (Myrtaceae) | Tree | 1 | - | 1 | - |
| *Eucalyptus punctata* (Myrtaceae) | Tree | - | 1 | - | - |
| *Eupomatia laurina* (Eupomatiaceae) | Shrub | 1 | 1 | - | 1 |
| *Ficus coronata* (Moraceae) | Tree | 1 | - | - | 1 |
| *Ficus rubiginosa* (Moraceae) | Tree | 1 | - | - | - |
| *Fieldia australis* (Gesneriaceae) | Vine | 1 | - | - | 1 |
| *Gratiola nana* (Scrophulariaceae) | Forb | 1 | - | - | - |
| *Hedycarya angustifolia* (Monimiaceae) | Tree | 1 | - | - | - |
| *Hydrocotyle laxiflora* (Apiaceae) | Forb | 1 | - | - | - |
| *Lastreopsis acuminata* (Dryopteridaceae) | Fern | 2 | 2 | - | 3 |
| *Lastreopsis microsora* subsp. *microsora* (Dryopteridaceae) | Fern | 1 | - | - | - |
| *Lepidosperma laterale* (Cyperaceae) | Sedge | 1 | 1 | 1 | - |
| *Leptopteris fraseri* (Osmundaceae) | Fern | 1 | 1 | 1 | - |
| *Leptospermum trinervium* (Myrtaceae) | Shrub | 1 | 1 | 1 | - |
| *Leucopogon lanceolatus* (Epacridaceae) | Heath-Shrub | - | 1 | - | - |
| *Libertia paniculata* (Iridaceae) | Forb | 1 | - | - | - |
| *Lindsaea microphylla* (Lindsaeaceae) | Fern | 1 | - | - | - |
| *Liparis reflexa* (Orchidaceae) | Lithophyte | - | - | - | 1 |
| *Logania albiflora*(Loganiaceae) | Shrub | - | - | 1 | - |
| *Lomandra filiformis* subsp. *filiformis* (Lomandraceae) | Rush | 1 | 2 | 2 | - |
| *Lomatia silaifolia* (Proteaceae) | Shrub | 1 | - | - | - |
| *Marsdenia rostrata* (Asclepiadaceae) | Vine | 1 | - | - | - |
| *Microsorum scandens* (Polypodiaceae) | Vine | 1 | 1 | - | 1 |
| *Morinda jasminoides* (Rubiaceae) | Vine | 1 | 1 | 1 | 1 |
| *Muellerina celastroides* (Loranthaceae) | Epiphyte | 1 | - | - | - |
| *Nematolepis squamea* subsp. *squamea* Rutaceae | Shrub | 1 | 1 | 1 | - |
| *Notelaea longifolia* (Oleaceae | Shrub | 1 | 1 | - | - |
| *Omalanthus populifolius* (Eupomatiaceae | Shrub | 1 | - | - | - |
| *Oplismenus aemulus* (Poaceae) | Tussock grass | 1 | - | - | - |
| *Pandorea pandorana* (Bignoniaceae) | Vine | 1 | 1 | 1 | 1 |
| *Parsonsia leichhardtii* (Apocynaceae) | Vine | - | - | - | 1 |
| *Parsonsia purpurascens* (Apocynaceae) | Vine | 1 | 1 | 1 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| *Pellaea falcata* var. *falcate* (Adiantaceae) | Fern | - | - | - | 1 |
| *Pellaea falcata* var. *nana* (Adiantaceae) | Fern | 3 | 2 | 1 | - |
| *Persoonia linearis* (Proteaceae) | Shrub | 1 | 1 | - | 1 |
| *Pittosporum undulatum* (Pittosporaceae) | Tree | 1 | - | - | - |
| *Rapanea variabilis* (Myrsinaceae) | Shrub | - | 1 | - | - |
| *Rubus hillii* (Rosaceae) | Vine | 1 | 1 | - | 1 |
| *Rubus moluccanus* var. *trilobus* (Rosaceae) | Vine | 1 | 1 | - | 1 |
| *Rubus parvifolius* (Rosaceae) | Vine | - | - | - | 1 |
| *Rupicola ciliata* (Epacridaceae) | Heath-Shrub | - | 1 | - | - |
| *Sarchochilus falcatus* (Orchidaceae) | Epiphyte | 1 | - | - | - |
| *Schoenus apogon* (Cyperaceae) | Sedge | 1 | - | - | - |
| *Schoenus melanostachys* (Cyperaceae) | Sedge | 1 | 1 | 1 | - |
| *Scutellaria humilis* (Lamiaceae) | Forb | 1 | - | - | - |
| *Smilax glyciphylla* (Smilacaceae) | Vine | 1 | 1 | 1 | 1 |
| *Stellaria flaccida* (Caryophyllaceae) | Forb | 1 | - | - | - |
| *Sticherus flabellatus* var. *flabellatus* (Gleicheniaceae) | Fern | 4 | 2 | 2 | 2 |
| *Stylidium graminifolium* (Stylidiaceae) | Forb | - | 1 | - | - |
| *Stypandra glauca* (Phormiaceae) | Forb | - | 1 | - | - |
| *Styphelia tubiflora* (Epacridaceae) | Heath-Shrub | - | - | 1 | - |
| *Tmesipteris parva* (Psilotaceae) | Epiphyte | 1 | - | - | - |
| *Todea barbara* (Osmundaceae) | Fern | 2 | 2 | - | 2 |
| *Trophis scandens* (Moraceae) | Vine | 1 | - | - | - |
| *Wollemia nobilis* (Araucariaceae) | Tree | 4 | 3 | 3 | 4 |
| *Xanthorrhoea glauca* (Xanthorrhoeaceae) | Grass-tree | 1 | - | - | - |

**Table 2. Growth forms, based on Walker & Hopkins (1990), of the vascular plant species associated with the *Wollemia nobilis***

| Growth Form | Number of species |
|---|---|
| Tree | 14 |
| Shrub | 12 |
| Heath Shrub | 4 |
| Tree Fern | 2 |
| Grass Tree | 1 |
| Vine | 15 |
| Fern | 20 |
| Forb | 9 |
| Sedge | 3 |
| Rush | 1 |
| Tussock Grass | 2 |
| Epiphyte | 3 |
| Lithophyte | 2 |
| Total | 88 |

**Table 3. Plant species occurrences at and between sites**

| | Site 1 | | Site 2 | | Site 3 | | Site 4 | | All Sites | |
|---|---|---|---|---|---|---|---|---|---|---|
| No. species | 68 | | 43 | | 31 | | 31 | | 88 | |
| No. species at 1 site | 31 | 46% | 8 | 19% | 4 | 13% | 5 | 16% | 49 | 56% |
| No. species at 2 sites | 6 | 9% | 3 | 7% | 4 | 13% | 4 | 13% | 8 | 9% |
| No. species at 3 sites | 15 | 22% | 16 | 37% | 9 | 29% | 7 | 23% | 16 | 18% |
| No. species at 4 sites | 15 | 22% | 15 | 35% | 15 | 48% | 15 | 48% | 15 | 17% |

**Table 4. Similarity between site plant species coverages (for species >1.0% similar)**

| | Average % Coverage | % Similar | Cumulative % Similar |
|---|---|---|---|
| *Ceratopetalum apetalum* | 50 | 6.32 | 6.32 |
| *Blechnum cartilagineum* | 26.25 | 5.05 | 11.36 |
| *Wollemia nobilis* | 26.25 | 4.86 | 16.22 |
| *Acmena smithii* | 14.63 | 3.42 | 19.63 |
| *Dicksonia antarctica* | 9 | 3.31 | 22.94 |
| *Sticherus flabellatus* var. *flabellatus* | 11.63 | 3.05 | 26.00 |
| *Doryphora sassafras* | 14 | 2.66 | 28.66 |
| *Dracophyllum secundum* | 1.75 | 1.73 | 30.39 |
| *Lastreopsis acuminata* | 5.25 | 1.62 | 32.01 |
| *Todea barbara* | 2.25 | 1.44 | 33.45 |
| *Elaeocarpus reticulatus* | 0.5 | 1.22 | 34.68 |
| *Asplenium flabellifolium* | 0.5 | 1.22 | 35.90 |
| *Parsonsia purpurascens* | 0.5 | 1.22 | 37.12 |
| *Pandorea pandorana* | 0.5 | 1.22 | 38.35 |
| *Morinda jasminoides* | 0.5 | 1.22 | 39.57 |
| *Smilax glyciphylla* | 0.5 | 1.22 | 40.79 |
| *Lomandra filiformis* subsp. *filiformis* | 1.63 | 1.16 | 41.95 |
| *Pellaea falcata var. nana* | 4.63 | 1.11 | 43.06 |
| *Blechnum patersonii* | 4 | 1.07 | 44.13 |

**Table 5. Proportion of species common to combinations of sites**

| | |
|---|---|
| Site1 & Site 4 | 30% |
| Site 3 & Site 4 | 32% |
| Site 3 & Site 1 | 35% |
| Site 2 & Site 4 | 42% |
| Site 2 & Site 1 | 43% |
| Site 2 & Site 3 | 50% |

**Table 6. Plant species coverage differences between sites for species with >1.1% dissimilarity scores**

| **Sites 2 and 3** | **42.79% Dissimilar** | |
|---|---|---|
| | **Dissimilarity %** | **Cumulative %** |
| *Lastreopsis acuminata* | 1.75 | 1.75 |
| *Todea barbara* | 1.75 | 3.50 |
| *Blechnum patersonii* | 1.70 | 5.20 |
| *Doryphora sassafras* | 1.69 | 6.89 |
| **Sites 2 and 4** | **44.12% Dissimilar** | |
| | **Dissimilarity %** | **Cumulative %** |
| *Calochlaena dubia* | 2.58 | 2.58 |
| *Lomandra filiformis* subsp. *filiformis* | 1.73 | 4.31 |
| *Pellaea falcata* var. *nana* | 1.71 | 6.02 |
| *Blechnum patersonii* | 1.67 | 7.69 |
| **Sites 1 and 2** | **46.48% Dissimilar** | |
| | **Dissimilarity %** | **Cumulative %** |
| *Blechnum patersonii* | 1.85 | 1.85 |
| *Doodia aspera* | 1.81 | 3.66 |
| *Blechnum nudum* | 1.21 | 4.87 |
| *Backhousia myrtifolia* | 1.21 | 6.08 |
| *Sticherus flabellatus* var. *flabellatus* | 1.17 | 7.26 |
| *Acmena smithii* | 1.17 | 8.43 |
| **Sites 3 and 4** | **50.18% Dissimilar** | |
| | **Dissimilarity %** | **Cumulative %** |
| *Lastreopsis acuminata* | 3.02 | 3.02 |
| *Lomandra filiformis* subsp. *filiformis* | 2.01 | 5.04 |
| *Todea barbara* | 2.00 | 7.04 |
| *Calochlaena dubia* | 1.93 | 8.96 |
| **Sites 1 and 4** | **52.87% Dissimilar** | |
| | Dissimilarity % | Cumulative % |
| *Calochlaena dubia* | 2.03 | 2.03 |
| *Pellaea falcata* var. *nana* | 1.99 | 4.02 |
| *Doodia aspera* | 1.99 | 6.01 |
| *Blechnum nudum* | 1.33 | 7.34 |
| *Backhousia myrtifolia* | 1.33 | 8.68 |
| *Doryphora sassafras* | 1.29 | 9.97 |
| *Sticherus flabellatus* var. *flabellatus* | 1.28 | 11.26 |
| **Sites 1 and 3** | **53.63% Dissimilar** | |
| | **Dissimilarity %** | **Cumulative %** |
| *Doodia aspera* | 2.02 | 2.02 |
| *Doryphora sassafras* | 1.96 | 3.98 |
| *Lastreopsis acuminata* | 1.38 | 5.36 |
| *Todea barbara* | 1.38 | 6.75 |
| *Blechnum nudum* | 1.35 | 8.10 |
| *Backhousia myrtifolia* | 1.35 | 9.45 |
| *Pellaea falcata var nana* | 1.31 | 10.76 |
| *Sticherus flabellatus* var. *flabellatus* | 1.31 | 12.07 |
| *Acmena smithii* | 1.31 | 13.38 |

*Floristic variation between sites*

While there is high congruence in canopy species composition across the four sites, analyses of all plant species records reveals variation in floristic composition. Site 1 contained more species than the other sites including more than twice that of the similar sized site 4 (Table 3). Compared to the other sites, site 1 also contained over three-fold the number and proportion of plant species that were only found at one site. 15 (17%) plant species were recorded in one site, 16 (18%) were recorded in two sites, 8 (9%) were recorded in three sites, and 49 (56%) were recorded in all sites (Table 3). However, only three of the 31 species recorded only at site 1 had greater than 1% cover, and none of the species unique to sites 2, 3 or 4 had greater than 1% cover.

When considering all plant species presence / absence, the four sites are 57% similar. Site 2 was most similar to all other sites in a plant species presence biplot, expressed as an MDS ordination on Bray-Curtis similarities (Figure 4), but sites 1, 3 and 4 were almost equidistant from each other. Based on Bray-Curtis similarities of species present (Figure 4), and on the percentage of species common to any two sites (Table 5), sites 2 and 3 are the most similar, then sites 2 and 1 or sites 2 and 4, then sites 1 and 3, 3 and 4, with sites 1 and 4 being least similar. The plant species that were most responsible for the similarity between the sites were *Ceratopetalum apetalum*, *Blechnum cartilagineum* and *Wollemia nobilis* (Table 4). Almost half of the difference in site species coverage for species >1.1% dissimilarity was due to absence of species from a site (Table 6).

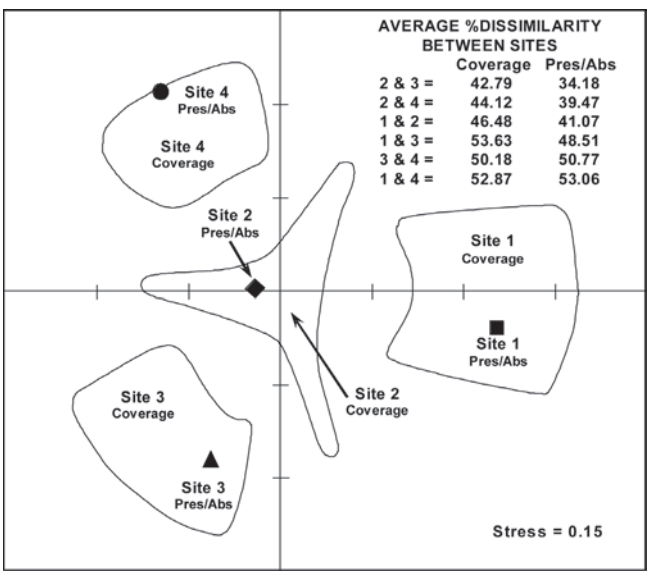


**Fig. 4.** Non-metric multi-dimensional scaling (MDS) ordination of Bray Curtis similarities from double root-transformed species presence and percentage cover ratings for *Wollemia nobilis* sites 1 to 4. Each site's plant species presence is represented on the plot as a single point. Plant species percent coverage of each study site is represented by a closed curve delimiting the possible range of similarities.

## Discussion

Most of the vascular plant species associated with *Wollemia nobilis* are common species of the canyons and gorges of the Blue Mountains region west of Sydney (Floyd 1990, Bell 1998). The vegetation at all sites of *Wollemia nobilis* is similar to the description of warm temperate rainforest sub-alliances 36 and 37 in Floyd (1990). This type of rainforest is widespread in the Blue Mountains and Wollemi National Parks. Postulations about why the *Wollemia nobilis* itself is so restricted are to be discussed elsewhere (J. Benson and T. Auld unpublished data).

Dominance of fern species at the different sites may reflect differences in humidity and light. For example, most of site 4 is dominated by *Blechnum cartilagineum*, that can tolerate relatively dry conditions and high light situations while *Sticherus flabellatus* var. *flabellatus* dominates the ground cover at site 1. The latter does not tolerate its root system drying out (Jones & Clemesha 1981) and tends to grow in lower light situations than *Blechnum cartilagineum*. This indicates the ground cover at site 1 is probably on average wetter than site 4. The higher floristic diversity of site 1 can probably be explained by its larger area and diverse micro-habitats compared to the other sites. Site 1 includes a large canyon, a narrow side canyon, a large watercourse and a larger range of aspects than the other sites.

Fire history can alter the boundaries and floristic composition of rainforest. The presence of *Eucalyptus piperita* at sites 1 and 3 and *Eucalyptus punctata* at site 2 within the *Wollemia nobilis* groves, indicates there were sufficient gap openings in the past for *Eucalyptus* seed to germinate and grow into adult trees. These gaps were possibly caused by disturbance events such as rock falls, windfalls or bushfire. It is likely that burning logs and branches have fallen into *Wollemia nobilis* groves from slopes above the clifflines at the sites. Some fires at the sites may have been patchy, others may have burnt the whole site. The smallest site, site 3, that contains six, small *Wollemia nobilis* trees growing next to sclerophyll vegetation composed of *Allocasuarina torulosa*, *Leptospermum trinerium* and *Eucalyptus piperita*, may be susceptible to more frequent fire than the other three sites.

The long-term survival of *Wollemia nobilis* will depend on a number of factors including maintaining its habitat and excluding or controlling pathogens. If associated angiosperm tree species such as *Ceratopetalum apetalum* and *Doryphora sassafras* are demonstrated to be out-competing *Wollemia*, in the absence of intermittent disturbance, this raises the issue of whether human-induced disturbance would be an appropriate management response to maintain the *Wollemia* populations. It is suggested that further monitoring and research is required before such action is taken.

Recent tests have revealed that the root pathogen *Phytophthora cinnamomi* has infected some trees at site 1 (Brett Summerell pers. comm.). In vitro experiments have revealed that *Wollemia* is susceptible to *Phytophthora cinnamomi* (Bullock et al. 2000) particularly when the trees are stressed. While it is not known how the pathogen arrived, site 1 is known to have been visited illegally by a number of people over the last 10 years. Illegal visitation could also result in the trampling of *Wollemia* seedlings and erosion of the shallow soil on the steep slopes where the tree grows. For these reasons the location and juxtaposition of the groves of *Wollemia nobilis* have not been released to the general public.

## Acknowledgements

Mr Chris Pavich of the Parks and Wildlife Division of NSW Department of Environment and Conservation assisted with the field work. The Wollemi Pine Recovery Team provided comments on the manuscript.

## References

Bell, S.A.J. (1998) Wollemi National Park vegetation survey: a fire management document. Report to NSW National Parks and Wildlife Service (NPWS Upper Hunter District: Muswellbrook).

Bullock, S., Gunn, L.V. and Summerell, B.A. (2000) Pathogens of the Wollemi Pine, *Wollemia nobilis*. *Australasian Plant Pathology* 29: 211–214.

Department of Environment and Conservation NSW (2007) Wollemia nobilis (Wollemi Pine) Recovery Plan (DEC NSW: Hurstville).

Floyd, A.G. (1990) *Australian Rainforests in New South Wales* (Surrey Beattie & Sons: Sydney).

Jones, D.L. & Clemesha, S.C. (1981) *Australian Ferns and Fern Allies* (Reed: Sydney).

Jones, W.G., Hill, KD. & Allen, J.M. (1995) *Wollemia nobilis*, a new living Australian genus and species in the Araucariaceae. *Telopea* 6: 2–3.

Peakall, R., Ebert, D., Scott, L., Meagher, P., and Offord, C. (2003) Comparative genetic study confirms exceptionally low genetic variation in the ancient and endangered relictual conifer, *Wollemia nobilis* (Araucariaceae). *Molecular Ecology* 12: 2331–2343.

Poore, M.E.D. (1955) The use of phytosociological methods in ecological investigations. I. The Braun-Blanquet system. *Journal of Ecology* 43: 226–244.

Sokal, R.R. & Rohlf, F.J. (1995). Biometry, Freeman, New York, 887pp.

Walker, J. & Hopkins, M.S. (1990) Vegetation. In McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. & Hopkins, M.S. *Australian Soil and Land Survey Field Handbook* (Inkata Press: Melbourne).

Manuscript accepted 24 July 2007