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Distribution, habitat preferences and population sizes of two threatened tree ferns, *Cyathea cunninghamii* and *Cyathea* x *marcescens*, in south-eastern Australia.

Ross J. Peacock[1,2], Alison Downing[2], Patrick Brownsey[3] and David Cameron[4]

[1]Office of Environment and Heritage, NSW Department of Premier and Cabinet, c/o Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, AUSTRALIA
[2]Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia
[3]Museum of New Zealand Te Papa Tongarewa, PO Box 467, Wellington 6140, NEW ZEALAND
[4] Department of Sustainability and Environment, Arthur Rylah Institute for Environmental Research, PO Box 137 Heidelberg Victoria 3084, AUSTRALIA.
[1]Author for correspondence: ross.peacock@mq.edu.au

***Abstract**:* The distribution, population sizes and habitat preferences of the rare tree ferns *Cyathea cunninghamii* Hook.f. (Slender Tree Fern) and F1 hybrid *Cyathea* x *marcescens* N.A.Wakef. (Skirted Tree Fern) in south-eastern Australia are described, together with the extension of the known distribution range of *Cyathea cunninghamii* from eastern Victoria into south-eastern New South Wales. Floristic and ecological data, encompassing most of the known habitat types, vegetation associations and population sizes, were collected across 120 locations. Additional information was sought from literature reviews, herbarium collections and field surveys of extant populations.

Cyathea cunninghamii is widespread, with the majority of populations occurring in Tasmania and Victoria, one population in south-eastern NSW and a disjunct population in south-eastern Queensland; *Cyathea* x *marcescens* is confined to south and eastern Victoria and south and north eastern Tasmania. Both taxa occur on King Island in Bass Strait. Both taxa have a near coastal distribution with most populations occurring in sub-coastal hinterland and escarpment forests with a median altitude of 288 m. Hierarchical cluster analysis of floristic data across the species' geographic range identified six vegetation communities ranging from rainforest to damp sclerophyll forest. Their micro-habitat preferences were consistently identified as steeply incised gullies of minor headwater streams of coastal and sub-coastal ranges with a plentiful moisture regime and geomorphic protection from extreme stream flow events, flooding and bank scouring. Sporophyte recruitment was associated with exposed soil of stream banks and edges of constructed walking tracks.

Population sizes of both taxa are small with the majority of populations consisting of less than five adult individuals, with total populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* estimated at 919 and 221 mature individuals respectively.

Population extinctions in Victoria and Tasmania have primarily been associated with outlier populations in regions subject to agricultural land clearance, habitat modification and changes to fire regimes in crown forests. Non-anthropogenic mortality was associated with land slips, tree falls and stream bank scouring by flood water. Conservation of the hybrid *Cyathea* x *marcescens* necessitates the preservation of habitats where both *Cyathea cunninghamii* and *Cyathea australis* occur in close proximity to substrates suitable for spore germination. In future, molecular techniques may prove useful for field identification of juvenile stages, facilitating selection of progeny of *Cyathea cunninghamii* and *Cyathea* x *marcescens* for cultivation and re-introduction to sites of previous or possible future extinctions.

Key Words: Tree fern, *Cyathea australis, Cyathea cunninghamii, Cyathea* x *marcescens,* threatened species, Australia, hybrids, Cyatheaceae

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Introduction

Tree ferns are of considerable ecological and aesthetic significance in moist forest communities of south eastern Australia. Due to their appeal to professional botanists, naturalists and the general public, tree ferns have been extensively studied and reported for their ecophysiological tolerances (Hunt et al. 2002, Volkova et al. 2009, 2010a,b,c), their horticultural and amenity use (Anon 1873, Attenborough 1997, Braggins & Large 2004, Jones & Clemesha 1976, Robbin 1985, Garrett 1998, Unwin & Hunt 1996, Wardlaw 1997) and their role as keystone species in forest regeneration dynamics (Gaxiola et al. 2008, Ough & Murphy 2004, Smale et al. 1997). The important role tree ferns play in the ecology of forest systems has been recognised in some of the earliest Australian and New Zealand forest ecological studies (Patton 1933, Petrie et al. 1929, Pope 1924, 1926). More recently they have been the subject of increased scientific study as a result of export harvest regulations (Department of Natural Resources & Environment 2002, Forest Practices Board 2005), on-ground management (Forest Practices Board 2003), their potential for production and sale from plantation estates (Unwin & Hunt 1997), regional conservation assessments (Garrett 1997) and their role as host substrates for vascular and non-vascular epiphytes across multiple continents (e.g. Beever 1984, Ford & Gibson 2000, Floyed & Gibson 2006, Gillman & Ogden 2005, Mehltreter et al. 2005, Page & Brownsey 1986, Peacock & Duncan 1994, Roberts 2002, Roberts et al. 2003, 2005). Of the tree fern species present in New South Wales (*Dicksonia antarctica*, *Dicksonia youngiae*, *Cyathea australis*, *Cyathea cooperi*, *Cyathea cunninghamii*, *Cyathea leichhardtiana*, *Todea barbara*), Victoria (*Dicksonia antarctica*, *Cyathea australis*, *Cyathea cunninghamii*, *Cyathea leichhardtiana*, *Cyathea* x *marcescens*, *Todea barbara*) and Tasmania (*Dicksonia antarctica*, *Cyathea australis*, *Cyathea cunninghamii, Cyathea* x *marcescens*, *Todea barbara*) the only taxa of conservation significance across their range are *Cyathea cunninghamii* and *Cyathea* x *marcescens*. *Cyathea leichhardtiana* is considered vulnerable (Flora and Fauna Guarantee Act 1988 Section 10) and threatened (Department of Sustainability and Environment 2005) in Victoria due to its limited distribution to the far eastern corner of that State.

The Slender Tree Fern, *Cyathea cunninghamii* (Cyatheaceae) (Figure 1), has a tall, narrow, erect trunk (caudex) to 20 metres high, from 7 to 20 cm in diameter (up to 28 cm in New Zealand), with a small crown of fronds (Duncan & Neyland 1986, Entwisle 1994). Reproductive structures are the most reliable diagnostic features and the indusia are well formed, prominent, more or less enclosing the sori when young, but opening to form a hood-like structure with a notch at the margin at maturity (Duncan & Neyland 1986, Bostock pers. comm. 2007).

In Australia *Cyathea cunninghamii* is known from Tasmania, Victoria, New South Wales and Queensland. The Tasmanian populations are almost exclusively near-coastal and are distributed discontinuously from the Southern Forests, the Tasman Peninsula, the east and west coast, the north west and King Island (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania 2011a). In Victoria *Cyathea cunninghamii* is recorded from the Otway Ranges, Yarra Ranges, South Gippsland and Wilsons Promontory, and from East Gippsland. For decades, the status of *Cyathea cunninghamii* in NSW has been unclear and its occurrence was either questioned (Jones & Clemesha 1976) or dismissed (Wakefield 1975). A specimen collected by the principal author in 1989 from a single plant growing in Maxwells Flora Reserve in Nadgee State Forest could not be precisely identified as the sori were over-mature and the key soral characters mostly lacking (Bostock 1998). In 1999 a subsequent collection from the same plant (NSW 449793–449796) was reproductively mature and determined as *Cyathea cunninghamii.* A specimen (BRI AQ331459) cited as *Cyathea cunninghamii* from Dorrigo northern NSW and referred to by Bostock (1998), was subsequently re-determined as *Cyathea australis* (Bostock pers. comm. 2007). There is a disjunct population in Lamington National Park in south-eastern Queensland from complex notophyll vine forest (Sattler & Williams 1999). This location is significant as it is the northern climatic limit of several cool subtropical species including the relictual species *Nothofagus moorei, Ochrosia moorei* and *Pandorea baileyana* (Sattler & Williams 1999, Queensland Department of Environment and Heritage 1998). The distribution in Lamington National Park has two known ‘centres’: Toolona Creek (the western branch of Canungra Creek) and Gwahlahla Falls at the headwaters of the Albert River. *Cyathea cunninghamii* is also known from New Zealand where it is not considered threatened (Brownsey 1979, Brownsey et al. 1985, Brownsey & Smith-Dodsworth 2000, de Lange et al. 2009). Nationally, *Cyathea cunninghamii* is listed as rare in the ANZECC Threatened Australian Flora list (1999) but is not listed in the Environment Protection and Biodiversity Conservation Act 1999. In Tasmania it has been listed as rare by the Flora Advisory Committee (1994) and endangered in the Threatened Species Protection Act 1995. In Victoria it is listed as threatened in the Victorian Flora and Fauna Guarantee Act 1988 Section 10 (2012). In Queensland, *Cyathea cunninghamii* is listed as near threatened in the Queensland Nature Conservation Act 1992. Currently there are no *Cyathea* species listed as threatened species under the NSW Threatened Species Conservation Act 1995.

The Skirted Tree Fern *Cyathea* x *marcescens* (Cyatheaceae) (Figure 2) (Wakefield 1942) is considered to be a sterile F1 hybrid between *Cyathea australis* and *Cyathea cunninghamii* (Wakefield 1975, Hill 1984, Duncan & Isaac 1994) with a range of morphological characteristics and ecological preferences evident in the offspring. The spores produced by *Cyathea* x *marcescens* are typical of those described for sterile fern hybrids (Wagner & Wagner 1986), being defective by nature of the collapse of the exospore and the absence of protoplast (Thiele pers. comm. 2011). *Cyathea* x *marcescens* differs from *Cyathea cunninghamii* in having a much thicker (up to 30 cm diameter) and shorter (to 10 metres) caudex, a very large, thick crown of fronds, rough, crumbly, black stipe bases and, usually, a persistent skirt of

Fig. 1. Two individuals of *Cyathea cunninghamii* at Dandenong Ranges National Park (Vic.) in plant community 1 (Wet sclerophyll Forests and Fern gullies, see Appendix1). The species often appears as a solitary adult plant or in small groups of 1-3 individuals in the deepest most sheltered portions of fern gullies. *Dicksonia antarctica* is the conspicuous understorey fern species. Photograph Ross Peacock

Fig. 2. Skirted Tree Fern, *Cyathea marcescens*, Dandenong Ranges National Park (Vic.) in plant community 1 (Wet sclerophyll Forests and Fern gullies, see Appendix1). Note the characteristic skirt of dried frond stipes attached to the caudex. Photograph Ross Peacock

dead fronds (see Figure 2). There are also differences in the reproductive structures. Sori of *Cyathea* x *marcescens* are produced in roughly semi-circular, low, cup-like indusia with irregular margins (Duncan & Isaac 1994, Bostock pers. comm. 2007).

Cyathea x *marcescens* is distributed across East Gippsland, Victoria, at Mount Drummer (lectotype location MEL 1513089 2 February 1941), Combienbar, Errinundra NP, Howe Ranges near the NSW border, Dandenong Ranges National Park east of Melbourne, Tarra-Bulga NP in South Gippsland and numerous reserves in the Otway Ranges (Walsh & Entwisle 1994). In Tasmania, it has been recorded at Marsh Creek and Little Beach Creek near Elephant Pass in the north-east of the state, at Fortescue Bay in the south and at Grassy River on King Island (Garrett 1997, Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011b). While *Cyathea* x *marcescens* was not described until 1942 (Wakefield 1942), specimens of uncertain status were collected from 1880 in Victoria and Tasmania, identified initially as *Cyathea medullaris* and later re-determined as *Cyathea* x *marcescens.* Nationally *Cyathea* x *marcescens* is not listed by the Environment Protection and Biodiversity Conservation Act 1999**.** However, it is listed as endangered in Tasmania under the Tasmanian Threatened Species Protection Act 1995 but has not been listed by the Tasmanian Flora Advisory Committee (1994). In Victoria it is listed as vulnerable in the Advisory List of Rare or Threatened Plants (2005) but is not listed in the Flora and Fauna Guarantee Act Threatened Species List (2012).

Precise identification of young plants has been difficult as *Cyathea cunninghamii* can take 20–30 years to reach sexual maturity and accurate identification has been based on characteristics of the sori. This task is made more difficult by the range of variation seen in provenances of *Cyathea* x *marcescens*, intermediate between the two parent species (Keel 1993).

This study was undertaken to determine the distribution, population sizes and habitat preferences of the rare tree ferns *Cyathea cunninghamii* and *Cyathea* x *marcescens* in south eastern Australia and also to report on the extension of the known distribution range of *Cyathea cunninghamii* into New South Wales.

Methods

Distribution

Distributional data for *Cyathea cunninghamii* and *Cyathea* x *marcescens* were compiled from literature sources, herbarium collections, databases held by government agencies and from interviews with field naturalists. Publically available national databases, such as the Australian Virtual Herbarium (AVH: www.chah.gov.au/avh) and Atlas of Living Australia (ALA: www.ala.org.au) were examined; however the policy of denaturing location, habitat and population information for rare plant species limits their utility where data matching from multiple sources is required to compile an accurate database (see Kooyman et al. 2012). For Victoria, the Royal Botanic Gardens Melbourne MELISR database was used to extract herbarium data, and the Department of Sustainability and Environment VROT population database was used to extract records from incidental sources and definable areas. Quadrat data, which included either or both taxa, was extracted from the Victorian Department of Sustainability and Environment Flora Information System. For New South Wales, Queensland and Tasmania herbarium data was also extracted from the specimen databases, and the specimen collections directly examined. The compiled distributional data was validated with duplicate or redundant records removed. The compiled distribution data were used to develop a strategy to plan population field surveys which addressed pertinent gaps in current knowledge of the species distribution of each taxa, population sizes, habitat preferences and threatening processes, using approaches advocated by Keith (2000).

Population sizes

Adult population sizes were estimated from published and unpublished literature, herbarium collections, floristic databases and from field searches of known or reported populations. Unlike most vascular plant species, where population sizes are usually estimated using a sampling and prediction approach, populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* in most cases were so small, discrete and limited in spatial extent that the adult plants could be subject to a direct census. Confidence in the population size estimates was therefore generally high except for the largest populations (50–200 adult individuals) where a sampling process was adopted.

Habitat descriptions from the literature and herbarium data were used to focus field searches to areas where there was a higher probability of detection. Plot-less traverses were conducted within suitable habitats in the vicinity of known or reported populations to refine population estimates and determine population extent. Where multiple population estimates for the same locality were available in the literature the most recent was used.

In order to minimise the risk of incorrect identification, only individuals with a caudex were used to estimate the size of extant populations. Estimates of the number of young sporophytes present were made during field searches but were not included in the estimate of population sizes due to the difficulty of accurate identification. When herbarium records were used to determine population sizes, a population was considered distinct if the record held sufficiently precise information to determine that the population could be recognised as geographically distinct from other collections in the immediate vicinity.

An expert approach was adopted to estimate the pre-European populations of both taxa for each region. The extant distribution was compared to the known extent of both taxa from herbarium data and naturalists' publications from the late nineteenth century, and intersected with the extent and degree of habitat modification, land clearance, wildfire, timber harvesting, poaching and non-anthropogenic events in those regions from the time of European settlement. For each region and taxon a simple formula was followed where the existing population size of each taxon was given a confidence interval based on the assumed adequacy of the existing survey effort in suitable habitat multiplied by a population 'expansion' factor derived from the above parameters (eg proportion of suitable habitat land cleared versus undisturbed etc). .

Table 1. Adult population characteristics for *Cyathea cunninghamii* and *Cyathea marcescens* throughout their range in Victoria, Tasmania, NSW and Queensland (includes all reliable records from those states).

	Cyathea cunninghamii	*Cyathea* x *marcescens*
Mean population size	7.7	5.9
Median population size	3	4
Total number of individuals	919	221

Habitat Preferences

Floristic data on extant populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* were compiled from public databases to describe habitat preferences, floristic affinities and broad scale distribution. An initial quantitative examination of the floristic data was undertaken to identify gaps in spatial coverage and un-sampled vegetation communities where both taxa were known from the literature or herbarium records. Additional floristic sampling was then undertaken in the Dandenong Ranges, South, Central and East Gippsland in Victoria and in southern New South Wales.

Floristic data were collected using 30 x 30m quadrats within a uniform stand of vegetation. Where plant communities were less than 30 m wide, for example along creeks, the quadrat shape was altered and a rectangle that enclosed the same area was sampled. All vascular plant species in each quadrat were assigned a visually assessed combined cover abundance value. Cover was measured in the field as projective foliage cover using the Walker & Tunstall (1981) definition. Structural information was collected on the height, cover and dominant species of each recognisable vegetation stratum in addition to a general habitat description of elevation, aspect, geology, soils, ground cover and disturbance history. Nomenclature follows Walsh & Stajsic (2007) for Victoria and Baker & de Salas (2012) for Tasmania.

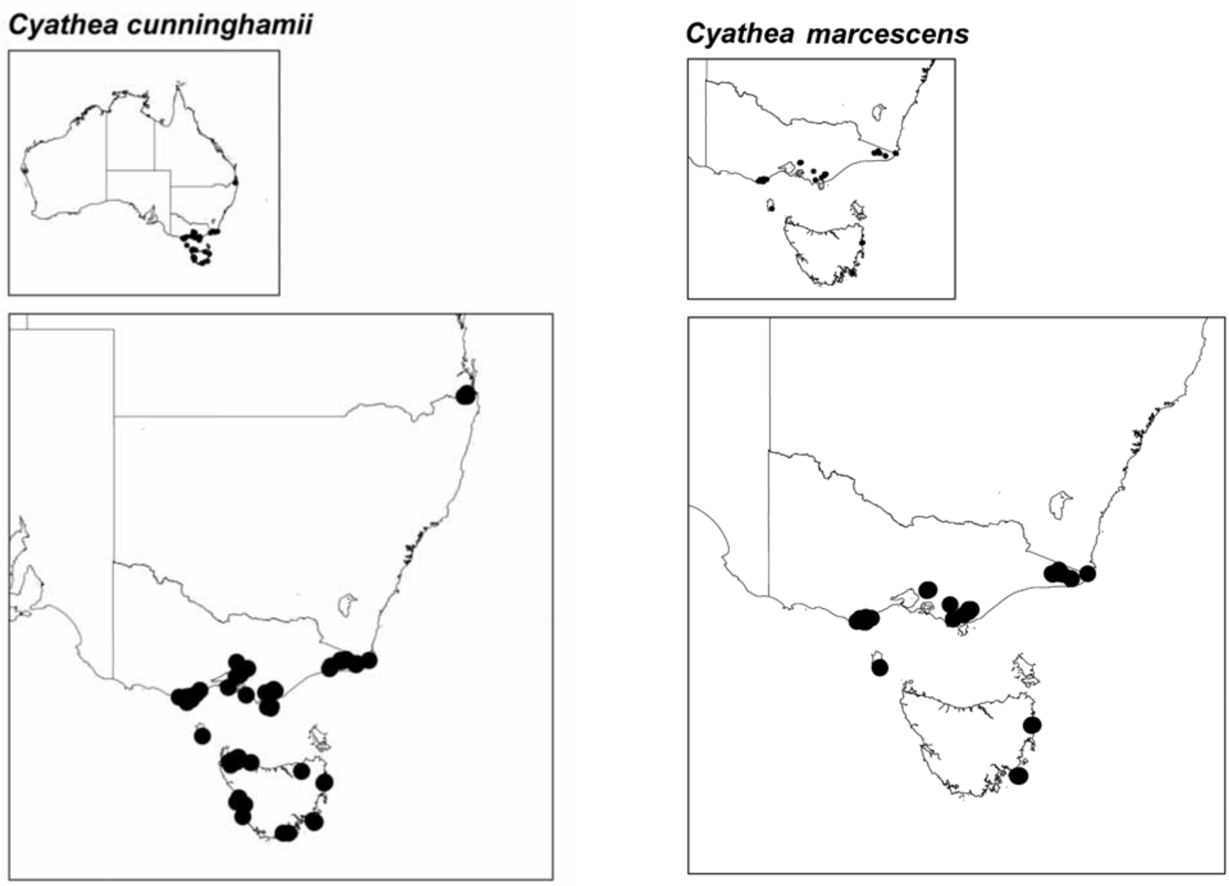

Fig. 3. Distribution of *Cyathea cunninghamii* (3a, 3b) and *Cyathea marcescens* (3c, 3d) in Australia (Atlas of Living Australia 2012a,b). Owing to the sensitive nature of precise locations for rare and/or endangered species, these maps are intended only as a guide to the distribution of each taxon.

Table 2a. Number of adult populations and their size estimates for *Cyathea cunninghamii* and *Cyathea* x *marcescens* throughout Victoria, Tasmania, New South Wales and Queensland (includes all reliable records from those states).

	Cyathea cunninghamii			*Cyathea* x *marcescens*		
	Number of populations	Total number of adult plants	Median number of individuals per population	Number of populations	Total number of adult plants	Median number of individuals per population
Tasmania	18	238	8	4	38	6
Dandenong Ranges, Victoria	1	19	19	2	23	9
East Gippsland, Victoria	25	115	3	10	53	4
Otway Ranges, Victoria	38	127	3	11	23	1
Central Highlands, Victoria	1	1	1	-	-	-
South and Central Gippsland, Victoria	32	403	3	9	84	-
New South Wales	1	1	1	-	-	-
Queensland	1	15	15	-	-	-
Total	117	919		36	221	

Table 2b. Estimated pre-European adult populations sizes for *Cyathea cunninghamii* and *Cyathea* x *marcescens* throughout Victoria, Tasmania, New South Wales and Queensland taking historical events and impacts into account.

Region	***Cyathea cunninghamii***	***Cyathea marcescens***	**Historical impacts**
Tasmania	700	120	Land clearance, agricultural development, severe wildfire events in 1897, 1934 & 1967
Yarra Ranges, Victoria	120	80	Land clearance, wildfires in 1851 and 1939, poaching, weed infestation, windthrow, encroachment
East Gippsland, Victoria	500	150	Habitat modification associated with extensive forest grazing and burning in the 1800s and timber harvesting in 1900s, wildfires in 1939 and 1983 and overall decline in lowland rainforest habitat, alluvial creek mining and prospecting and associated burning in 1800s
Otway Ranges, Victoria	500	60	Wildfires in 1919, 1939, decline in rainforest and fern gully habitat associated with timber harvesting, fire and potentially *Nothofagus* canopy dieback, land clearance for agriculture
Central Highlands, Victoria	100	10	Wildfires in 1926, 1939 and 2009, decline in rainforest and fern gully habitat associated with timber harvesting, alluvial creek mining and associated burning in 1800s
South and Central Gippsland, Victoria	1500	300	Land clearance and habitat modification in west and south Gippsland due to agricultural development, land clearance in central and south Gippsland due to plantation development and wildfires in 1898, 1914, 1932, 1939 and 1965
New South Wales	30	10	Integrated forest harvesting, impacts of wildfires in 1939, 1952 and 1980 on remnant rainforest in far south eastern NSW, rainforest canopy dieback since 1980s and associated tree windthrow into creeks
Queensland	40	-	Habitat along creeks associated with waterfalls is considered relatively stable
Total	3500	730	

The visually assessed cover abundance values derived from each 30 x 30 m quadrat were converted to the mid-point of the respective cover class. An association matrix of the 120 quadrats and 191 species was compiled using the Bray-Curtis distance measure (Bray & Curtis 1957). As a preliminary step in reducing noise in the data set a frequency distribution of average Bray-Curtis distance measures was constructed and statistical outliers identified as those quadrats with a mean distance measure of greater than three standard deviations from the grand mean distance measure of all pair-wise comparisons. This step removed the single quadrat from Lightning Falls at Lamington National Park Queensland which alone introduced 21 unique warm temperate and sub-tropical taxa to the analysis. The data set used in the analysis was reduced to 119 quadrats and 170 species.

The multivariate relationships between floristic composition and environmental correlates were examined using ordination and classification. The ordination technique was non-metric multidimensional scaling (NMS). NMS ordinations in the global form were derived from 50 multiple runs, using 10 different random starting configurations, with a maximum of 100 iterations. Ordinations were performed in 1–3 dimensions, and the minimum stress solutions for each dimension examined. Stress is 'a measure of departure from monotonicity in the relationship between the dissimilarity (distance) in the original p-dimensional space and distance in the reduced k-dimensional ordination space' (McCune & Mefford 1999). The two dimensional solution was chosen as the appropriate number of dimensions (axes) following an examination of the final stress versus the number of dimensions. The stability criterion for terminating successive iterations was 0.001. The axis scores from the two dimensional solution were saved and examined graphically using two dimensional plots rotated on the x-axis and through graphical overlays. Hierarchical clustering was performed on same mid-point converted percent cover floristic data using the unweighted pair-group method (UPGMA) (Sokal & Michener 1958). The distance measure used was Bray-Curtis (Bray & Curtis 1957).

Dendrograms were generated from the cluster analysis as a visual representation of the binary tree structure. A level in each hierarchy was sought where floristic groups could be defined robustly with respect to floristic composition, vegetation structure and group indicator species. Floristic groups were recognised by drawing a vertical line through the dendrogram at a consistent point in the scaling of the fusion history using the Wishart (1969) objective function. Species fidelity with floristic groups was assessed using indicator species analysis (Dufrene & Legendre 1997). Relative abundance in floristic groups was defined as the average abundance of a given species in a floristic group divided by the average abundance of that species across all floristic groups, expressed as a percentage. Indicator values were calculated and a Monte Carlo randomisation test of significance applied to test the observed maximum indicator values for each species against the indicator value in all other groups. The randomisation test was run 10,000 times. Multivariate analyses were implemented in PC-ORD v. 6.08 (McCune & Mefford 1999). The results of the indicator species analysis were presented only for species with a relative frequency of >50%.

Results

Distribution

Cyathea cunninghamii is the more widespread taxon, being distributed from south-east Queensland to southern Tasmania (Figures 3a, 3b), while *Cyathea* x *marcescens* is limited to a subset of this area from East Gippsland to southern and eastern Tasmania (Figures 3a, 3b). Both taxa have a near-coastal distribution with more than 40% of the populations occurring within 5 km. of the coast (Figure 4). The populations furthest from the coast include those at Errinundra National Park in Victoria and Lamington National Park in Queensland. The altitudinal distribution of both taxa (median = 288 m) is indicative of the primary habitat being sub-coastal hinterland and escarpment forests (Figure 5), the exception being the higher altitude populations at Errinundra National Park in eastern Victoria and Lamington National Park in south-east Queensland. The core areas of distribution are the escarpment ranges of south and central Gippsland and the Otway Ranges of Victoria. The primary outlier population of *Cyathea cunninghamii* is in Lamington National Park in south-east Queensland, approximately 1000 km north of the nearest population of *Cyathea cunninghamii* at Nadgee in south-eastern New South Wales.

Population sizes

There are very few populations of either *Cyathea cunninghamii* or *Cyathea* x *marcescens*. The total number of populations for *Cyathea cunninghamii* and *Cyathea* x *marcescens* was estimated at 117 and 36 respectively, with a median population size of 3 individuals for *Cyathea cunninghamii,* and 4 individuals for *Cyathea* x *marcescens,* and an estimated total of 919 and 221 individuals respectively (see Tables 1 & 2). Based on the number of documented local population extinctions and the extent of land use change in those regions where both taxa occur, these numbers are significantly less than those (3500 and 730 mature individuals respectively) that have been estimated for prior to European settlement in Australia (Table 2b).

The largest populations of both *Cyathea cunninghamii* and *Cyathea* x *marcescens* occur in Tarra Bulga National Park in South Gippsland Victoria with an estimated 200 adult individuals of *Cyathea cunninghamii* (Ashwell 1991) and at least 50 adult individuals of *Cyathea* x *marcescens* (Healey, K., 22 June 1953, MEL 2152284A, in correspondence dated 12 July 1953 to J.H. Willis attached to sheet, cited by Bryant 2010). The next most populous regions are the Otway Ranges and East Gippsland, Victoria. The largest number of populations of both taxa is in the Otway Ranges, Victoria (Table 2) where they are found in steeply incised wet sclerophyll and rainforest habitats in various national parks and associated reserves. In East Gippsland both taxa are

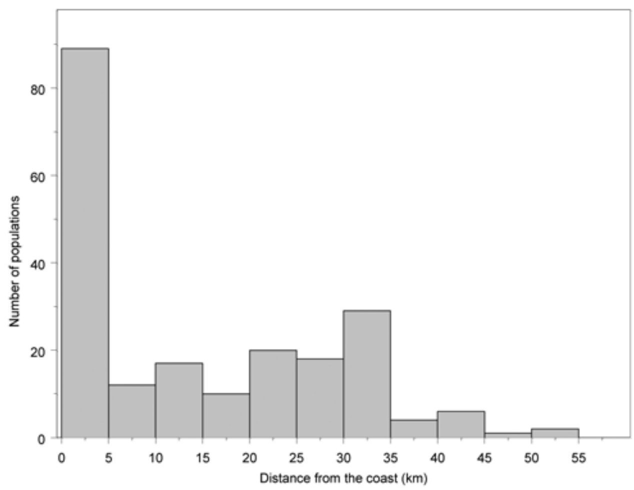

Fig 4. The near coastal distribution of 223 spatially distinct populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* throughout their range in eastern Australia. Over 40% of the extant populations of both taxa occur within 5 km of the coast

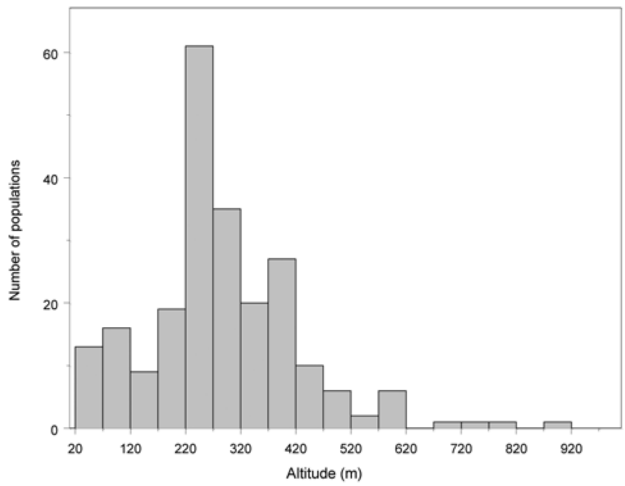

Fig. 5. The altitudinal distribution of the 223 spatially distinct populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* throughout their range in eastern Australia. The median altitude is 288 m.

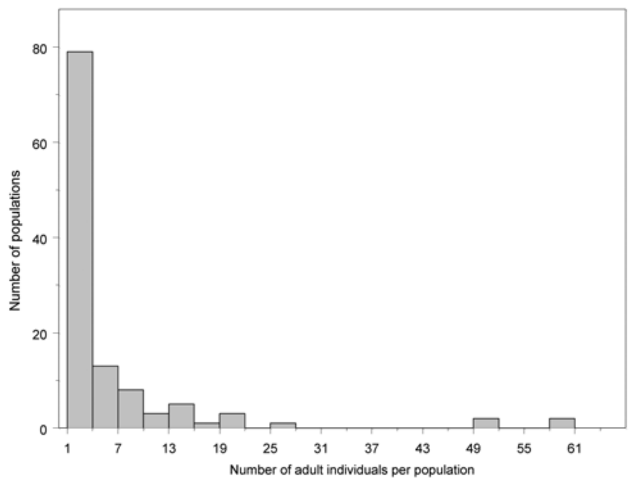

Fig. 6a: Distribution of *Cyathea cunninghamii* population sizes across the species range (n=117). The single largest population estimated to include 200 individuals at Tarra-Bulga National Park is excluded to maintain a comparable x-axis scale to Figure 6b.

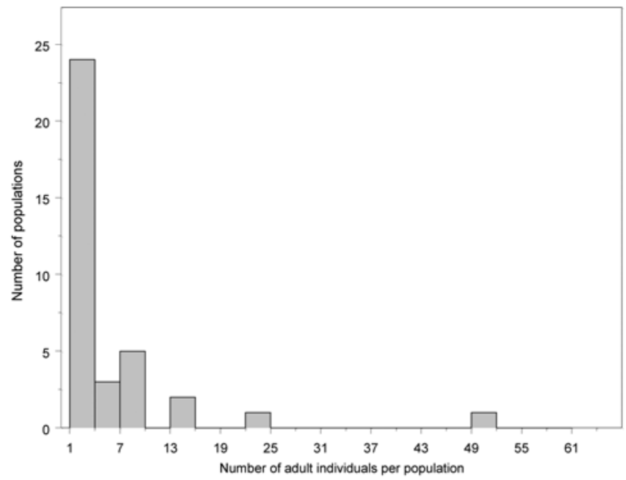

Fig. 6b: Distribution of *Cyathea* x *marcescens* population sizes across the taxon range (n=36).

widely distributed in coastal (e.g. Mallacoota and the Howe Ranges), near-coastal and escarpment forests, with the largest populations located in the Goolengook River catchment of Errinundra National Park (Lobert et al. 1991). In spite of the large area of potential habitat (wet sclerophyll forest, fern gullies and rainforest) in the Victorian central highlands, there is only a single cultivated *Cyathea cunninghamii* recorded beside a walking track at Badger (Coranderrk) Creek on land managed by Melbourne Water. This individual was reportedly planted prior to 1981 (R.L. Hill pers. comm. 1989). In New South Wales, *Cyathea cunninghamii* is known from a single plant in Maxwell's Flora Reserve in Nadgee State Forest.

Across the 117 known populations of *Cyathea cunninghamii,* more than 60% had five or less individuals (Table 2, Figure 6a). Similarly, population estimates for 36 populations of *Cyathea* x *marcescens* indicate that more than 70% had five or less individuals (Table 2, Figure 6b).

Repeated population surveys at key sites have permitted examples of population decline, increase and local extinctions to be documented for both taxa (Table 3). The majority of cases involve documented declines and local extinctions following habitat modification and land clearing for agriculture, although stochastic events including flash flooding and wind storm damage can be locally significant. The only known example of a population increasing in number is at Kallista, Dandenong Ranges National Park in Victoria, in an area which has not been subject to wildfire since 1939. In this case the population estimates date from 1879 to 2012 with the 2012 population of both taxa comprising 36 adult individuals.

Habitat preferences

The classification of 119 sites and 170 species was truncated at the six group level in the fusion history where six vegetation communities were recognised (Figure 7). These include: Group 1 – Wet sclerophyll Forests and Fern gullies; Group 2 – Warm and Cool Temperate overlap Rainforest; Group 3 – Cool Temperate Rainforest; Group 4 – Lowland Wet Sclerophyll Forest; Group 5 – Lowland Damp Sclerophyll Forest and Rainforest Ecotones; Group 6 – Mid-elevation Damp Sclerophyll Forest and Rainforest Ecotones. The dominant floristic and habitat characteristics of these communities are summarised in Appendix 1 and by their relative species abundance scores in Appendix 2.

Seven sites were identified as being distinct but could not be described adequately with the available data and are annotated in the dendrogram as unclassified.

Two dimensional NMS ordination of full floristic composition of the 119 plots and 170 species for sites that included either

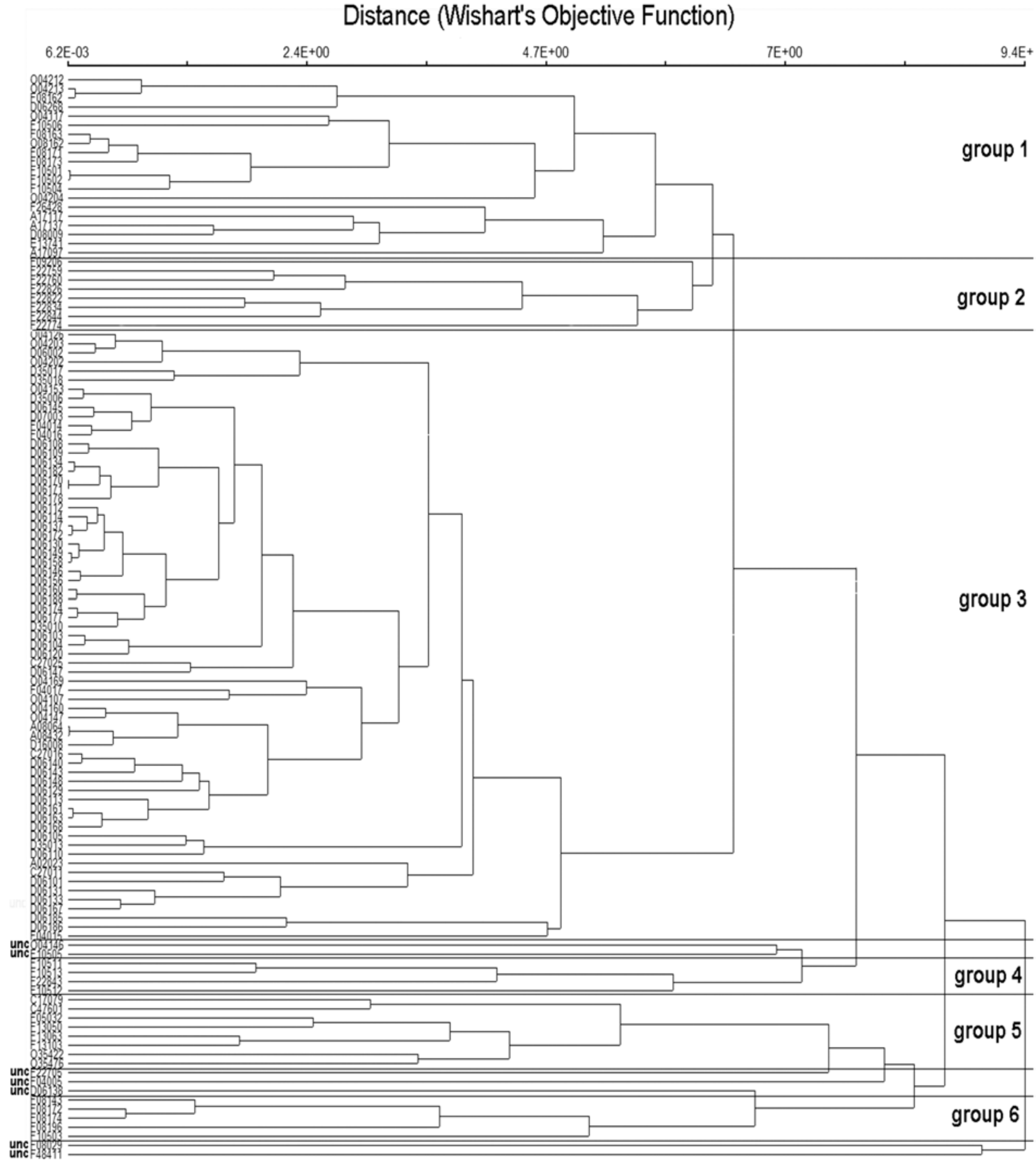

Fig. 7. Vegetation associations of *Cyathea cunninghamii* and *Cyathea marcescens* throughout their range in New South Wales, Victoria and Tasmania. The hierarchical floristic classification of 119 plots was truncated at the six group level and seven plots remained unclassified - 'unc'.

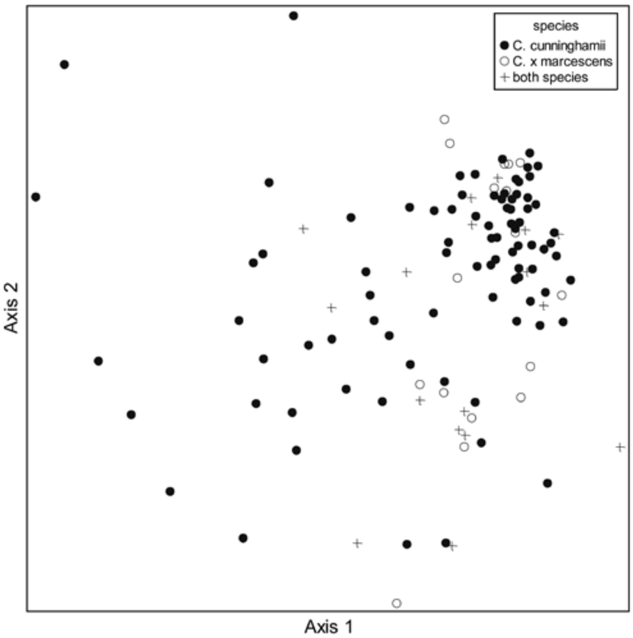

Fig. 8. Two dimensional NMS ordination of full floristic composition of 119 plots and 170 species for the six floristic groups shown in Figure 5. The site labels identify plots that included either *Cyathea cunninghamii*, *Cyathea* x *marcescens* or both taxa at the one location. A small number of sites include only the hybrid taxon *Cyathea* x *marcescens*.

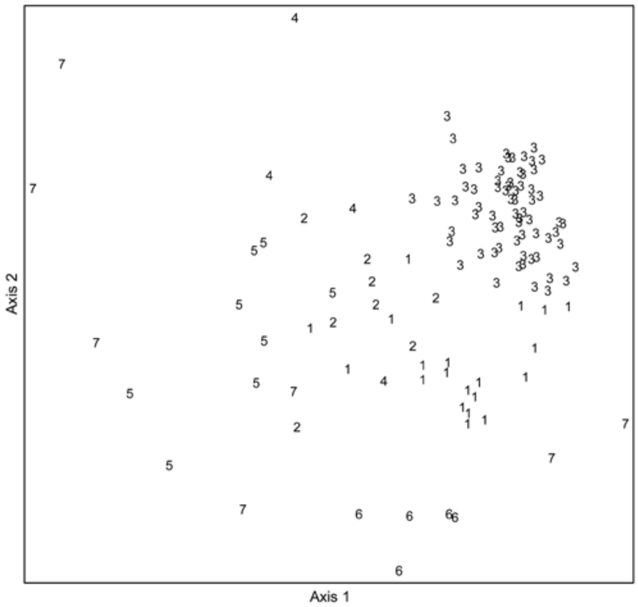

Fig. 9. Two dimensional NMS ordination of full floristic composition of 119 plots and 170 species. The six floristic groups are labelled 1-6 (Appendix 1-2); label '7' represents the unclassified ('unc') plots from Fig. 6. Minimum stress in relation to the two dimensional solution was 19.4.

Cyathea cunninghamii, or *Cyathea* x *marcescens,* or both, at the one location, is shown in Figure 8. Model fitting statistics for the ordination of floristic cover data are given in Table 3.

Two dimensional NMS ordination of full floristic composition of 119 plots and 170 species for the six floristic groups is shown in Figure 9.

Cyathea cunninghamii occurs widely across all geographic regions and environments from simple microphyll fern forest in south-eastern Queensland through both warm and cool temperate near coastal forest types in New South Wales, Victoria and Tasmania. *Cyathea* x *marcescens* is limited to wet sclerophyll forests and fern gullies, and mid-elevation East Gippsland damp sclerophyll forest and rainforest ecotones of Victoria, south-eastern New South Wales and Tasmania (Appendix 1). In Tasmania, the majority of extant sites occur within 3 km of the coast and between 20 to 150 m above sea level.

Cyathea cunninghamii occurs in each of the six recognised vegetation communities and *Cyathea* x *marcescens* occurs in all but one of these communities: Group 4 (Lowland Wet Sclerophyll Forest). The second parent species, *Cyathea australis*, occurs in all of the communities except one: Group 4 (Lowland Wet Sclerophyll Forest). Group 4 has only four sites, three of which are from southern Tasmania where *Cyathea australis* is infrequent (Appendix 1).

Floristics of populations from the Victorian Otway Ranges and South Gippsland regions were the most similar and homogeneous, while floristics of populations from East Gippsland were the most heterogeneous (Figure 10), being found across a broader suite of environments from gentle slopes of lowland valleys, to moderate to deeply incised gullies of headwater streams. The Goolengook populations of East Gippsland (Errinundra National Park) are unique in their association with rainforest with overlapping components of cool and warm temperate rainforest, a characteristic not found elsewhere in the Victorian populations except for the East Errinundra River section of Errinundra National Park.

Table 3. Model fitting statistics for the ordination of floristic cover data in two dimensions and coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space. Increment and cumulative R-squared were adjusted for any lack of orthogonality of axes.

Axis	**r-squared**		**Minimum stress in real data**	**r-squared and % orthogonality with each axis**	
	increment	**cumulative**		**axis 1**	**axis2**
1	0.495	0.495	31.1	-	0.199, 96.0%
2	0.309	0.803	19.4	-	-

The single record of *Cyathea cunninghamii* in NSW is associated with *Eucryphia moorei* temperate rainforest. All other Victorian and Tasmanian populations are associated with cool temperate rainforest, wet forest, or in the case of lowland East Gippsland, warm temperate rainforest.

Discussion

Distribution

Fern distribution in Australia tends to be closely associated with the distribution of different forest types (Page & Clifford 1981), and this appears to be the situation with respect to the types of plant communities in which *Cyathea cunninghamii* and *Cyathea* x *marcescens* occur. The temperate rainforest and fern gully communities of Victoria and Tasmania, while not being as species rich in ferns as the tropical forests of north Queensland, are characterised by the presence of many individual ferns belonging to few species (Page & Clifford 1981). The typical eastern Australian fern gully dominated by *Dicksonia antarctica* and, to a lesser extent by *Cyathea australis,* is one example of this phenomenon. Within these fern gully associations, micro-habitat preferences can be identified from empirical evidence based on extensive field population surveys across the range of both taxa. While both taxa have distributions which initially appear to parallel the distribution of cool temperate rainforest and wet sclerophyll forest in Victoria, they are curiously absent from the extensive tracts of cool, wet sclerophyll vegetation in the Victorian central highlands. This is also the situation in Tasmania where most populations of *Cyathea cunninghamii* occur close to the coast, between 20 – 150 m above sea level (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011a). Factors controlling their distribution are difficult to determine because of the very small number of known populations across a geographic range extending from south-east Queensland to southern Tasmania and the ability of tree fern species for long distance spore dispersal (Brownsey 2001). However, the general consensus for tree ferns is that rainfall and temperature either at the continental, regional or local scale primarily influence their distribution (Brownsey 2001, Lehmann et al. 2002). In an area well known for its overlap of southern boundaries of many northern plant species and the eastern boundary of many southern and western plant species, the occurrence of a single adult *Cyathea cunninghamii* in New South Wales, only five kilometres directly north of the Victorian-New South Wales border in Nadgee State Forest, is both a significant extension of that species distribution and an example of the challenge in understanding the factors controlling the species distribution.

In order to determine which factors may control distribution, it may be more useful to examine the two taxa on a local scale. For example *Cyathea cunninghamii* may be locally plentiful in a particular fern gully in the Otway Ranges, but absent from many other seemingly suitable habitats elsewhere in the same region.

Undoubtedly, the characteristic feature of the ecology of both taxa is their micro-habitat preference for the stream banks of mountain forests, especially in areas of reliable, high rainfall (generally > 1200 mm) and high humidity. These stream banks may occur in a wide variety of floristic and structural vegetation communities, ranging from warm and cool temperate rainforests through to tall open forests and occasionally minor fern gullies of open forests. They include the type locality for *Cyathea* x *marcescens* in warm temperate rainforest, dominated by *Acmena smithii* and *Rapanea howittiana* at Alfred National Park in Victoria (Wakefield 1953) which is included in vegetation community six.

Ultimately, the distribution and survival of the hybrid *Cyathea* x *marcescens* is dependent on the presence of both parents, *Cyathea cunninghamii* and *Cyathea australis,* at the same location, with moist substrates suitable for spore germination, subsequent development of gametophytes, fertilization and growth of sporophytes. Field examination of a number of populations suggests that *Cyathea cunninghamii,* which has a requirement for a reliable and abundant water supply, is restricted to stream banks with a high water table. Preferred habitats are often in close proximity to waterfalls, (supposedly to benefit from increased humidity and higher light levels) and on shallow creek banks in upper catchments unlikely to be scoured by flash flooding. Early descriptions of the preferred habitat suggest that plants of *Cyathea cunninghamii* are to be found in ‘the coolest and deepest fern-gullies’ (Bond & Barrett 1934 p. 27) and in the ‘deepest, wettest part of the gully, with their roots almost in the water’ (Barfield 1974). Field observations also suggest the species preferred recruitment substrate is either open stream banks or cleared areas along walking tracks, consistent with the experimental evidence from New Zealand that the species high growth and mortality rates are linked to high photosynthetic rates (Bystriakova et al. 2011).

Cyathea australis, on the other hand, grows on a much greater range of substrates, in a much wider array of habitats, tolerating hotter and drier sites with higher light levels (Volkova et al. 2010a) than the moist, shaded creek banks on which *Cyathea cunninghamii* is found. *Cyathea* x *marcescens* grows on intermediate sites between *Cyathea cunninghamii* and *Cyathea australis* (Garrett 1996, Peacock pers. obs.).

The habitat preferences of *Cyathea cunninghamii* in New Zealand reflect those in Australia: damp gullies or rivers within low altitude forests on young soils (eg Bystriakova et al. 2010), protected from drought and cold. Brownsey (1979) suggested that the relative susceptibility of *Cyathea cunninghamii* to drought when compared to other *Cyathea* species, may be a limiting factor in its distribution in New Zealand. The species is almost absent from drier eastern side of both New Zealand islands, occurring up to 1000 m in elevation, (approaching the altitudinal limit of the species in Queensland) and is most commonly found in near-coastal habitats up to 50 km from the coast.

Population sizes

The limited size of most extant populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens* is not considered to be a recent phenomenon that might be associated with urban sprawl or agricultural or plantation development. Early accounts refer to *Cyathea cunninghamii* as a 'rather scarce fern' (Pitcher 1913 p. 10), 'now very uncommon in Tasmania' (Wakefield 1975) and in reference to the first collection of *Cyathea* x *marcescens* in 1880 from the Otway Ranges as 'only to be found occasionally' (Wakefield 1945), indicating that small population sizes are a characteristic of both taxa. In New Zealand, similar references report *Cyathea cunninghamii* as being 'one of the least plentiful of our tree-ferns… scattered sparsely along some of the gullies…only three or four specimens in the vicinity' (Crookes & Dobbie 1963) and 'only locally common despite its wide distribution' (Brownsey 1979).

Given that *Cyathea cunninghamii* appears to be a naturally uncommon species, it is inevitable that *Cyathea* x *marcescens* will also be of very limited distribution, since *Cyathea cunninghamii* is one of its parents. However, the very occurrence of *Cyathea* x *marcescens* in a mixed population may be contributing to the paucity of *Cyathea cunninghamii* individuals. In populations where adult plants of *Cyathea australis* greatly outnumber those of *Cyathea cunninghamii*, there will be a similar discrepancy in the number of gametophytes of each species. Hence there will be limited opportunities for fertilisation between gametophytes of *Cyathea cunninghamii.* Those opportunities will be limited still further if significant numbers of gametophytes are 'wasted' in cross-fertilisation with *Cyathea australis* when its gametophytes are present in overwhelming numbers. In other words, every adult individual of *Cyathea* x *marcescens* represents the potential loss of at least one individual of *Cyathea cunninghamii*, and possibly more, since hybrids are less likely to develop than the parent species as a result of genetic imbalance.

Threats

Inferring threat levels and the probability of population extinction is challenging in the absence of large data sets and independent, systematic observations. While approaches using collection data have been trialled (Burgman et al. 1995) their implementation requires care because their statistical basis assumes the chance of a species being collected does not change over time and the true chance of being collected reflects the relative abundance of the species. In the case of *Cyathea cunninghamii* and *Cyathea* x *marcescens,* the added complication exists that many of the earliest collections had imprecise localities recorded and a contemporary search of the population is therefore difficult to plan. Secondly, methods are now needed to merge and perhaps weight different sources of distributional data for both taxa. Herbarium collections have the greatest taxonomic reliability. However from the late 1980s, databased floristic plot survey records surpassed collection data in quantity and extent in Victoria and consequently form an important source of data in inferring threat status. Threats to both taxa have been extensively communicated in both Tasmania (Forest Practices Authority 2012, Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011c) and Victoria (Gutowski 1996, Department of Sustainability & Environment (undated), Department of Natural Resources & Environment 2002) as part of legislated threatened species review programs. Examples of the range of identified threats and resulting local population extinctions or decline Victoria and Tasmania are included in Table 4.

Non-anthropogenic threats

The very low population estimates for *Cyathea cunninghamii* and *Cyathea* x *marcescens* in regional Victoria and Tasmania highlight the sensitivity of both taxa to stochastic events such as flood, fire, drought and storms. Floods are one of the key natural limitations to their distribution. Stream bank scouring as a result of flash flooding appears to be one of the most destructive factors in limiting recruitment of *Cyathea cunninghamii.* Neither *Cyathea cunninghamii* nor *Cyathea* x *marcescens* is known to grow on the banks of larger streams and rivers subject to peak flows exceeding normal river bank levels. Garrett (1997) reported that the 1988 floods in northern Tasmania destroyed mature specimens of *Cyathea cunninghamii* and one specimen of *Cyathea* x *marcescens.* Disturbance to headwater catchment areas, for example for forestry, agriculture or road construction, that modifies stream flow and increases scouring and sediment deposition, may have implications for the survival of *Cyathea cunninghamii* and possibly *Cyathea* x *marcescens,* both in terms of loss of mature specimens and in the negative impact on regeneration.

Wildfire has been identified for over a century as a threat to populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens.* Descriptions of the effects of wildfires were frequently graphic; '*disastrous fires, especially the great holocaust of January 1951* (in Wilsons Promontory National Park), *have reduced the occurrence of some rare kinds almost to vanishing point. The elegant Slender Tree-fern (*Cyathea cunninghamii*, Victoria's tallest fern), … are now extremely rare, localised and very seldom observed*' (National Parks Authority 1969 p. iv). Later references to *Cyathea cunninghamii* include populations becoming 'uncommon and vanishing as the result of fires' (Willis 1970) and 'because of fires and forest clearing is disappearing' (Barfield 1974). However, some early observers did not consider wildfire to be a threat to populations of either *Cyathea cunninghamii* or *Cyathea* x *marcescens;* for example, N.A. Wakefield (cited in Hunter 1942) stated that "*both areas* (Mt Drummer) *have been severely burned several times, and each time the patches of 'jungle' along the creeks have escaped and the ferns survived*". More recent observations indicate that these same populations which escaped the 1939 fires (Wakefield 1967) did not survive the 1983 Cann River wildfires and both taxa now only survive in adjacent rainforest stands.

Table 4. Examples of population declines and local extinctions for *Cyathea cunninghamii* and *Cyathea* x *marcescens* throughout their range in Victoria and Tasmania.

Species	Location	Initial population estimate and (date)	Most recent population estimate and (date)	Reason for change
Cyathea cunninghamii				
	Main Creek, southeast of Arthurs Creek Mornington Peninsula (Vic.)	unknown (1883)	Locally extinct by 1949 (Wakefield & Willis 1949)	agricultural land clearing
	Mt Burnett, Upper Pakenham (Vic.)	1 (date unknown)	Locally extinct (1989)	habitat modification
	Berwick (Vic.)	4 (1989)	Locally extinct (1999)	habitat modification
	Deadlock Creek Gorge, near Yarragon (Vic.)	3 (1960s)	Locally extinct (1989)	softwood plantation development
	Mount Disappointment Reference Area Plenty River headwaters Kinglake National Park (Vic.)	1 (1980s)	Locally extinct (2011)	severe wildfire
	Corinna, Pieman River (Tas.)	1 (1986)	Locally extinct (2011)	tree fall
	Grassy River King Island (Tas.)	5 (1990)	1 (2011)	falling trees during storms
	Circular Head district (Tas.)	Unknown (1940s)	Locally extinct (2011)	habitat loss, adjacent selective harvesting
Cyathea x *marcescens*				
	Grassy River King Island (Tas.)	5 (1990)	1 (1996)	falling trees during storms
	Lower Marsh Creek Forest Reserve (Tas.)	60 (1982)	24 (1986)	flash flooding
	Mt Drummer section Alfred National Park 'below the Springs' (Vic.)	(1941)		lectotype location, presumed lost during 1983 wildfires although persists nearby in unburnt rainforest

In February 2009, severe bushfires spread through Kinglake National Park, decimating populations of many mesic dependent ferns and their rainforest habitats. Just & Beardsell (2011) predicted that many fern species would be unlikely to recover in the near future because of the destruction of canopy cover and deep humus on the forest floor, and the replacement of rainforest with drier, more fire prone elements of sclerophyll forest. One such local extinction was the single known specimen of *Cyathea cunninghamii* observed by Cam Beardsell in 1988 in the headwaters of the Plenty River East Branch in the Mt Disappointment Reference Area of Kinglake National Park. The single specimen was associated with *Nothofagus cunninghamii* and *Atherosperma moschatum* in a highly protected gully which had escaped all previous known fires since 1729 (Ashton 2000).

The size and height of tree ferns can increase their extinction or disturbance risk (Mehltreter 2010) and for *Cyathea cunninghamii* its relatively large crop of fronds and tall narrow caudex increases its vulnerability to high winds. Mature specimens have been brought down by high winds in the Eaglehawk Neck area of Eastern Tasmania (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011a) and both *Cyathea cunninghamii* and *Cyathea* x *marcescens* have had their crowns blown out where populations were adjacent to clear felled forest in the Otway Ranges, Victoria (Roberts 1991). During the period 1990 – 1996, a number of specimens of *Cyathea* x *marcescens* were destroyed by falling trees following storms, for example on Grassy River at King Island and Lower Marsh Creek Tasmania (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011b).

Anthropogenic threats

Land clearance for agricultural development and associated burning probably represents the most significant historical threat to populations of the two taxa. In addition to clearing, other potential threats include: construction of farm roads, buildings and dams that may adversely affect hydrology; cultivation of crops with the potential to increase downstream siltation; trampling by stock; introduction of weed species; and use of pesticides and fertilizers (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011c). One of the largest known populations of *Cyathea cunninghamii* in Victoria occurs in the Kallista area near Melbourne, an area which is coming under increasing pressure from suburban development, recreation demands and weed invasion. The main threat for this population is weed invasion, particularly species that colonise the caudex such as ivy (*Hedera helix),* or species such as Wandering Trad (*Tradescantia fluminensis*) that form a dense cover over creek banks where most spore germination and growth of young sporophytes occurs.

The expansion of the dairy industry and gold prospecting in the nineteenth century, and the development of broad scale plantation estates in areas such as central Gippsland during the 1960s – 1970s (e.g. Deadlock Creek Gorge, Yarragon), probably led to the local extinction of smaller populations in Victoria and in northern Tasmania. Geographically isolated populations were most prone to local extinction, for example the Main Creek population at Arthurs Seat on Victoria's Mornington Peninsula (J.M. Baldry, 1883, MEL 224441A) which is extinct as a result of agricultural land clearing (Wakefield & Willis 1949). Land use intensification saw further populations become locally extinct in the 1970s in south Gippsland (Dumbalk east of Leongatha) which, in this case, reportedly also resulted in the sale of tree ferns to the horticultural trade during clearing (Scarlett 1980). The reduction of available habitat for tree fern species in Victoria is not a recent phenomenon, with Robbins (1945) referring to fern gully habitats as 'fast disappearing'.

Forest management practices (timber harvesting and fuel reduction) have the potential to adversely affect populations of *Cyathea cunninghamii* and *Cyathea* x *marcescens.* Presently, in all jurisdictions, both taxa are now protected via threatened species planning provisions and forest practices codes, although the strength of these approaches relies on the population being identified during the pre-harvesting planning process. Whether forest management has led to the diminution of the range of either taxon is debatable; several action statement reviews have argued this to be the case (e.g. Gutowski 1996), however direct evidence has often been lacking due to the absence of targeted population monitoring. In addition to possible changes to microclimate and hydrology, timber harvesting has the potential to increase exposure to high winds and consequent tree fall. The single known plant of *Cyathea cunninghamii* at Nadgee State Forest in NSW exists in a minor gully whose canopy of *Eucryphia moorei* rainforest has structurally deteriorated as a result of dieback from exposure and canopy branch blowout. The deterioration of this small rainforest stand is most likely a response to intensive harvesting without adequate buffering. The adjacent forest compartment was burnt by wildfire in 1952, harvested for sawlogs in the 1960s, harvested again for sawlogs and pulpwood in 1975–76 and burnt by a wildfire in 1980 (Forestry Commission of NSW 1988). The dedication of the flora reserve in 1988 over this remnant rainforest stand has focussed management efforts on fire protection.

Post-harvest burning to promote overstorey regeneration may pose a threat if poorly implemented on rainforest boundaries (Otway Ranges Environment Network 2004). The low frequency of hazard reduction burning and minimal disturbance from timber harvesting may have contributed to the survival of both taxa at several localities in the Goolengook catchment East Gippsland (Errinundra National Park). Similarly in Tasmania, there is the potential for both taxa to be affected by wildfires or from poorly implemented post-harvest burning (Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section 2011c).

The illegal taking of tree ferns for horticultural purposes has been a long term problem in Australia (Robbin 1985, Hodgson 2007) and has the potential not only to decimate populations but also to damage habitats from which the tree ferns have been taken. Permits to take tree ferns are now strictly controlled, for example: Department of Sustainability & Environment (Victoria) Application for a Permit to Take Protected Flora (2008); and the Forest Practices Authority (Tasmania) (2011) regulations. The collection of *Cyathea cunninghamii* for horticultural use (e.g. Pitcher 1913) is now unlikely and so is the harvesting of the starchy caudex apex for baiting animal traps (Bond & Barrett 1934). In Victoria, wild grown *Cyathea cunninghamii* has not been traded horticulturally since the early 1980s (Peacock pers. obs).

Long term human induced climate change is predicted to lead to a reduction in available habitats for *Cyathea cunninghamii* and *Cyathea* x *marcescens* in southern Australia as the climate becomes both warmer and drier. The Tasmanian, Victorian and NSW populations at present are located in the near-coastal ranges where climate change and increased climate variability have the potential to alter the extent of their suitable habitat. It may be possible to use the existing climate change scenarios to predict areas of potentially suitable habitats at higher elevations.

Conservation management

Cyathea cunninghamii and *Cyathea* x *marcescens* are variously considered in Australia as rare, vulnerable or endangered (Appendix 3). In New Zealand, *Cyathea cunninghamii* is not threatened (de Lange et al. 2009). The status of both taxa has not been assessed or decided by the Commonwealth Threatened Species Scientific Committee and therefore neither has been listed under the national Environment Protection and Biodiversity Conservation Act 1999. In view of the relative isolation of populations, and the small number of individuals that comprise each population, urgent consideration should be given to the nomination of *Cyathea cunninghamii.* The situation for *Cyathea* x *marcescens* is somewhat different. If locations where populations of *Cyathea cunninghamii* grow in close proximity to *Cyathea australis* are protected, there will always be the potential for spontaneous reproduction of hybrid offspring of *Cyathea* x *marcescens.*

The management, protection and recovery of existing populations of tree ferns in Tasmania has been comprehensively documented in the Flora Recovery Plan: Threatened Tasmanian Ferns (Threatened Species Section 2011c). In Tasmania the management objectives for *Cyathea cunninghamii* are to minimise the probability of extinction of subpopulations by ensuring habitat protection. This includes specific fire exclusion provisions, survey of surrounding areas for possibility of locating more populations in habitats with comparable characteristics, investigation of propagation techniques to repopulate areas from where the species has disappeared or to supplement existing populations. The success of these measures, in particular the provisions of the Forest Practices Code in Tasmania, has been evident in the recent discovery of new large populations of both taxa (e.g.

Leaman 2011) during pre-harvest planning. The survival of the F1 hybrid, *Cyathea* x *marcescens* requires the protection of locations where both parents, *Cyathea cunninghamii* and *Cyathea australis,* grow in close proximity to each other and where conditions for reproduction are favourable.

The relationship between *Cyathea cunninghamii, Cyathea australis* and their hybrid offspring *Cyathea* x *marcescens* appears to mirror the relationship reported elsewhere between parent fern species and their hybrids (Brownsey 1981, Smith & Grayum 1988, Kentner & Mesler 2000). In these instances one parent (like *Cyathea cunninghamii*) was restricted to moist, shady sites, the other (like *Cyathea australis*) able to colonise a much more varied range of sites, but generally those with lower moisture and higher light levels; taxa identified as hybrids (*Cyathea* x *marcescens*) occupied intermediate sites. Kentner & Mesler (2000) considered that this distribution of hybrids was explained as the result of environmentally mediated natural selection and only individuals with genotypes suited for various microclimates survived to reproductive maturity.

While it is clear that populations of both taxa have declined over the last two hundred years, the magnitude of this decline is difficult to quantify with several of the largest known populations only being discovered in the last twenty years. Additionally the rate at which new populations have been recorded has declined since the 1990s when remote forest areas were being actively surveyed for biodiversity prior to timber harvest planning.

Until recently, positive identification of young *Cyathea* species was not possible until plants reached maturity. By combining morphological characters together with allozyme and chloroplast DNA markers, using the techniques of Kentner & Mesler (2000), it should be possible to identify young sporophytes of both parent species and hybrid offspring. Additionally, recently developed tissue culture techniques (Fernandez et al. 1993, Goller & Rybczyński 2007, Higuchi et al. 1983, Kuriyama et al. 2004) may be useful in the formulation of techniques for the propagation of both *Cyathea cunninghamii* and *Cyathea* x *marcescens*, to ensure their survival. However, as long as locations where both *Cyathea australis* and *Cyathea cunninghamii* grow together are protected, it is highly likely that hybrid offspring (*Cyathea* x *marcescens*) will continue to occur spontaneously, as they do under conditions of controlled propagation using spores of both parents (Hill 1984). The importance of the co-occurrence relationship between *Cyathea cunninghamii* and *Cyathea* x *marcescens* was perhaps recognised as early as 1880 by a simple note accompanying a herbarium specimen that ‘they both grow in company with one another’ (MEL 2152287A 01/04/1880, Cape Otway Range, coll. Marriner, G.H. cited by Wakefield 1945 p. 126).

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References

Anon (1873) Tree Ferns. *The Garden* 4: 526–527.

Australian Virtual Herbarium (AVH) www.chah.gov.au/avh

ANZECC (1999) Australian & New Zealand Environment Conservation Council. List of Threatened Australian Flora. Environment Australia, Canberra.

Ashton, D.H. (2000) The environment and plant ecology of the Hume Range, Central Victoria. *Proceedings Royal Society of Victoria* 11(2): 185–278.

Ashwell, D.A. (1991) *A vegetation survey of Tarra-Bulga National Park, Victoria.* Parks Branch, National Parks and Public Land Division, Department of Conservation and Environment, East Melbourne, Vic. Arthur Rylah Institute for Environmental Research Technical report series No. 105.

Atlas of Living Australia (ALA) www.ala.org.au/

Atlas of Living Australia (2012a) *Cyathea cunninghamii* Hook.f. Slender Tree Fern: http://bie.ala.org.au/species/urn:lsid:biodiversity.org.au:apni.taxon:310904 Accessed 7 April 2012.

Atlas of Living Australia (2012b) *Cyathea* x *marcescens* N.A.Wakef. Skirted Tree Fern at http://bie.ala.org.au/species/Cyathea+x+marcescens Accessed 17 May 2012.

Attenborough, D. (1997) Life on my doorstep. *Gardens Illustrated* 24: 122.

Baker, M.L. & de Salas, M.F. (2012) A Census of the Vascular Plants of Tasmania and Index to the Student’s Flora of Tasmania and Flora of Tasmania Online. Tasmanian Herbarium, Hobart, Tasmania. http://www.tmag.tas.gov.au/__data/assets/pdf_file/0017/61703/2012_Census_of_Tasmanian_Vascular_Plants.pdf

Barfield, L. (1974) The slender tree-fern. *The Clematis* 13: 9–10.

Beever, J.E. (1984) Moss epiphytes of tree ferns in a warm temperate forest, New Zealand. *Journal of the Hattori Botanical Laboratory* 56: 89–95.

Bond, R.W. & Barrett, C. (1934) *Victorian Ferns: Descriptions of all the Species occurring in the State.* Field Naturalists Club of Victoria.

Bostock, P.D. (1998) Cyatheaceae In *Flora of Australia.* Volume 48. Ferns, gymnosperms and allied groups (A.E. Orchard & P.M. McCarthy Eds) pp. 193–205. ABRS/CSIRO, Australia.

Braggins, J.E. & Large, M.F. (2004) *Tree Ferns*. Timber Press Inc., Portland, Oregon.

Bray, J.R. & Curtis, J.T. (1957) An ordination of upland forest communities of southern Wisconsin. *Ecological Monographs* 27: 325–349.

Briggs J. D. and Leigh J. H. (1996) *Rare or threatened Australian plants*. CSIRO Publishing, Australia.

Brownsey, P.J. (1979) *Cyathea cunninghamii* in New Zealand. *New Zealand Journal of Botany* 17: 97–107.

Brownsey, P.J. (1981) A biosystematic study of a wild population of *Leptopteris* hybrids in New Zealand. *New Zealand Journal of Botany* 19: 343–352.

Brownsey, P.J. (2001) New Zealand's pteridophyte flora – plants of ancient lineage but recent arrival? *Brittonia* 53(2): 284–303.

Brownsey, P.J., Given, D.R. & Lovis, J.D. (1985) A revised classification of New Zealand pteridophytes with a synonymic checklist of species. *New Zealand Journal of Botany* 23: 431–489.

Brownsey, P.J. & Smith-Dodsworth, J.C. (2000) *New Zealand ferns and allied plants* (revised edition). David Bateman, Auckland.

Bryant. P. (2010) Research Report on the listing of Flora for Tarra-Bulga National Park (collected by Kara Healey & others) held at the National Herbarium of Victoria. Friends of Tarra-Bulga National Park Inc. http://home.vicnet.net.au/~bulga/friends/kara/rbg_report.pdf

Burgman, M.A, Grimson, R.C. & Person, S. (1995) Inferring threat from scientific collections. *Conservation Biology* 9(4): 923–928.

Bystriakova, N., Bader, M. & Coomes, D.A. (2011) Long-term tree fern dynamics linked to disturbance and shade tolerance. *Journal of Vegetation Science* 22(1): 72–84

Crookes, M. & Dobbie, H.B. (1963) *New Zealand Ferns* – 6th Edition. Whitcombe & Tombs Ltd., Christchurch.

de Lange P.J., Norton D.A., Courtney S.P., Heenan, P.B., Barkla, J.W. & Cameron, E.K. (2009) Threatened and uncommon plants of New Zealand (2008 revision). *New Zealand Journal of Botany* 47: 61–96.

Department of Natural Resources & Environment (2002). Victorian Tree-fern Management Plan 2001 – 2006. Department of Natural Resources & Environment, East Melbourne. http://www.dse.vic.gov.au/__data/assets/pdf_file/0008/102995/TreeFernManagementPlan.pdf

Department of Sustainability and Environment (2005) Advisory List of Rare or Threatened Plants in Victoria – 2005. Victorian Department of Sustainability and Environment, East Melbourne, Victoria. http://www.dse.vic.gov.au/__data/assets/pdf_file/0005/103388/Advisory_List_of_Rare_or_Threatened_Plants_in_Victoria_-_2005.pdf

Dufrene, M. & Legendre, P. (1997) Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs*. 67: 345–366.

Duncan, B. D. & Isaac, G. (1994) *Ferns and Allied Plants of Victoria, Tasmania and South Australia with distribution maps for the Victorian species*. Melbourne University Press.

Duncan, F. & Neyland, M. (1986) Tasmanian Tree Ferns: A Vegetative Key and Descriptions. *The Tasmanian Naturalist* 85: 2–8.

Entwisle, T.J. (1994) Cyatheaceae, In N.G. Walsh & T.J. Entwisle (Eds), *Flora of Victoria* 2: 67–70.

Environment Protection & Biodiversity Conservation Act 1999. http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=flora

Environmental Protection Agency (1992) *Nature Conservation Act*. Department of Environment & Resource Management, Brisbane. http://www.legislation.qld.gov.au/legisltn/current/n/naturecona92.pdf

Fernandez, H., Bertrand, A. & Sanchez-Tames, R. (1993) In vitro regeneration of *Asplenium nidus* L. from gametophytic and sporophytic tissue. *Scientia Horticulturae* 56(1): 71–77.

Flora Advisory Committee (1994) *Native higher plant taxa which are rare or threatened in Tasmania*. Edition 1. Species at Risk, Tasmania Flora. Parks and Wildlife Service, Tasmania.

Flora and Fauna Guarantee Act 1988 Section 10 Threatened List (2012). http://www.dse.vic.gov.au/__data/assets/pdf_file/0019/141580/201207-FFG-threatened-list.pdf

Floyed, A. & Gibson, M. (2006) Epiphytic bryophytes of *Dicksonia antarctica* Labill. from selected pockets of Cool Temperate Rainforest, Central Highlands, Victoria, *The Victorian Naturalist* 123(4): 229–235.

Ford, S. & Gibson, M. (2000) Lichens of the Soft Tree-fern *Dicksonia antarctica* Labill. in Victorian Rainforests. *The Victorian Naturalist* 117(5): 172–179.

Forest Practices Authority (2012) Tree Fern Management Plan for the Sustainable harvesting, Transporting or Trading of *Dicksonia antarctica* in Tasmania 2012. http://www.fpa.tas.gov.au/__data/assets/pdf_file/0005/58037/Revised_Tasmanian_treefern_management_plan_2012.pdf.

Forest Practices Board (2003) Tree Fern Identification and Management. Forest Practices Board. *Flora Technical Note Series No. 5. http://www.fpa.tas.gov.au/__data/assets/pdf_file/0020/58052/Flora_Tech_Note_05_Treefern_identification_and_management.pdf*

Forestry Commission of NSW (1988) Working Plan, Maxwell's Flora Reserve No. 116. Nadgee State Forest No. 125. Forests NSW, West Pennant Hills, New South Wales.

Garrett, M. (1996). *The Ferns of Tasmania. Their ecology and distribution***.** Tasmanian Forest Research Council, Hobart.

Garrett, M. (1997) Rare or Threatened Tasmanian Forest Ferns. A Report to the Tasmanian RFA Environment & Heritage Technical Committee. http://www.daff.gov.au/rfa/regions/tasmania/environment/ferns

Garrett, M. (1998) *Dicksonia antarctica* in Tasmania, some background to the arguments for and against large-scale harvesting from the wild. *Pteridologist* 3(3): 14–17.

Gaxiola, A., Burrows, L.E. & Coomes, D.A. (2008) Tree fern trunks facilitate seedling regeneration in a productive lowland temperate rainforest. *Oecologia* 155(2): 325–335.

Gillman, L.N. & Ogden, J. (2005) Microsite heterogeneity in litterfall risk to seedlings. *Austral Ecology* 30: 497–504.

Goller, K. & Rybczyński, J. J. (2007) Gametophyte and sporophyte of tree ferns in vitro culture. *Acta Societatis Botanicorum Poloniae* 76(3): 193–199.

Gutowski, A. (1996) Slender Tree-fern *Cyathea cunninghamii*, Draft Action Statement, Department of Natural Resources & Environment, Victoria.

Higuchi, H., Amaki, W. & Suzuki, S. (1987) In vitro propagation of *Nephrolepis cordifolia* Presl. *Scientia Horticulturae* 32(1): 105–113.

Hill, R. (1984) *Cyathea marcescens* propagation from spore? *Newsletter of the Fern Society of Victoria* 6: 14.

Hodgson, S. (2007) Tree thieves sent to jail. *Herald Sun.* http://www.heraldsun.com.au/news/more-news/tree-thieves-sent-to-jail/story-e6frf7kx-1111113170846 Accessed 18/04/2012.

Hunt, M.A, Davidson, N.J., Unwin, G.L. & Close, D.C. (2002) Ecophysiology of the Soft Tree Fern, *Dicksonia antarctica* Labill. *Austral Ecology* 27(4): 360–368.

Hunter, W. (1942) The new tree-fern. *The Victorian Naturalist* 59: 118.

Jones, D.L. & Clemesha, S.C. (1976) *Australian Ferns and Fern Allies with notes on their Cultivation.* A.H. & A.W. Reed, Sydney.

Just, K. & Beardsell, C. (2011) *Threatened Species Management Plan for Kinglake National Park.* Report 0971, Version 1.2, prepared for: Parks Victoria. 141 pp. http://www.iffa.org.au/IFFA-files/library/Threatened-Species-Management-Plan-Kinglake-National-Park-December2010-Version2-1.pdf

Keel, S. I. (1993) *On the Taxonomic Status of* Cyathea marcescens *Wakef. (Cyatheaceae).* Honours Thesis, Botany Department, Latrobe University.

Keith, D.A. (2000) Sampling designs, field techniques and analytical methods for systematic plant population surveys. *Ecological Management and Restoration* 1(2): 125–139.

Kentner, E.K. & Mesler, M.R. (2000) Evidence for natural selection in a fern hybrid zone. *American Journal of Botany* 87(8): 1168–1174.

Kooyman, R.M., Rossetto, M., & Laffan, S.W. (2012) Using Australian Virtual Herbarium data to find all the woody rain forest plants in Australia. *Cunninghamia* 12(3): 177–180.

Kuriyama, A., Kobayashi, T. & Maeda, M. (2004) Production of sporophytic plants of *Cyathea lepifera,* a tree fern, from in vitro cultured gametophyte*. Journal of the Japanese Society for Horticultural Science* 73: 140–142.

Leaman, T. (2011) New record of *Cyathea cunninghamii* (slender treefern) near Railton. Forest Practices News 10 (4):1–2 Forest Practices Authority, Hobart Tasmania. http://www.fpa.tas.gov.au/__data/assets/pdf_file/0007/58192/FPN_April_2011_vol_10_no_4.pdf

Lehmann, A., Leathwick, J.R. and Overton, J. McC. (2002) Assessing New Zealand fern diversity from spatial predications of species assemblages. *Biodiversity and Conservation* 11:2217–2238.

Lobert, B.O., Gillespie, G.R., Lunt, I.D., Peacock, R.J. & Robinson, D. (1991) *Flora and Fauna of the Goolengook Forest Block, East Gippsland, Victoria.* Department of Conservation & Environment, East Melbourne.

McCune, B. & Mefford, M.J. (1999) PC-ORD. *Multivariate Analysis of Ecological Data, Version 4.* MjM Software Design, Gleneden Beach, OR, USA. 237 pp.

Mehltreter, K., (2010) *Fern conservation*. In Mehltreter, K, Walker, L. R. & Sharpe, J. M. (Eds) Fern Ecology. Cambridge University Press, New York, NY.

Mehltreter, K., Flores-Palacios, A. & García-Franco, J.G. (2005). Host preferences of low-trunk vascular epiphytes in a cloud forest of Veracruz, Mexico. *Journal of Tropical Ecology* 21: 651–660.

National Parks Authority (1969) *The Ferns and Flowering Plants of Wilsons Promontory National Park.* National Parks Authority, State Public Offices, Treasury Place, Melbourne.

Nature Conservation Act 1992 http://www.legislation.qld.gov.au/LEGISLTN/CURRENT/N/NatureConWiR06.pdfld.

Otway Ranges Environment Network (2004) Nomination 191: Slender Tree Fern. http://www.oren.org.au/issues/naturecons/biodiversity/nominations/n191.htm Accessed 17.04.2012.

Ough, K. & Murphy, A. (2004) Decline in tree-fern abundance after clearfell harvesting. *Forest Ecology and Management* 199(1): 153–163.

Page, C.N. & Brownsey, P.J. (1986) Tree fern skirts: a defence against climbers and large epiphytes. *Journal of Ecology* 74: 787–796.

Page, C.N. & Clifford, H.T. (1981) Ecological biogeography of Australian conifers and ferns. In: A. Keast (Ed.) *Ecological Biogeography of Australia* pp. 473 – 498. W. Junk, The Hague.

Patton, R.T. (1933) Ecological studies in Victoria Part II. The fern gully. *Proceedings of the Royal Society of Victoria* 46: 117–129.

Peacock, R. J. & Duncan, F. (1994) Impact of logging on *Dicksonia antarctica* and associated epiphytes in Tasmanian wet eucalypt forests. *In Proceedings of International Forest Biodiversity Conference, Canberra, December 1994*. 'Conserving Biological Diversity in Temperate Forest Ecosystems - Towards Sustainable Forest Management'. Department of the Environment, Sport and Territories Canberra. p. 171-72

Petrie, A.H.K., Jarrett, P.H. & Patton, R.T. (1929) The vegetation of the Black's Spur region. A study in the ecology of some Australian mountain *Eucalyptus* forests. Part I. The Mature Plant Communities. *Journal of Ecology* 17: 223–249.

Pitcher, F. (1913) Some general remarks on ferns, with special reference to Victorian species. *The Victorian Naturalist* 30(1): 10–11.

Pope, A. (1924) The role of the tree fern in the New Zealand bush. Part 1. *New Zealand Journal of Science and Technology* 7: 52–61.

Pope, A. (1926) The role of the tree fern in the New Zealand bush. Part II. *New Zealand Journal of Science and Technology* 8: 85–98.

Queensland Department of Environment & Heritage (1998) Flora Data Analysis EH 1.1.4. Queensland CAR/RFA Steering Committee. Forest Assessment Unit, Queensland.

http://www.daff.gov.au/__data/assets/pdf_file/0003/48909/qld_se_eh114a.pdf

Robbin, J.M. (1985) Tree ferns – are we running out? *Australian Horticulture* 83(2):86–91.

Robbins, F. (1945) Some haunts of East Victorian ferns. *The Victorian Naturalist* 61: 196.

Roberts, I. (1991) Submission by Earth Resource Analysis on Rainforest and fire buffers. Victorian Department of Conservation & Environment Central Registry File 90/2329–1.

Roberts, N. (2002) *Tree ferns as a substrate for bryophytes and ferns in south-eastern Tasmania*. Unpublished honours thesis, School of Plant Science, University of Tasmania, Hobart.

Roberts, N.R., Dalton, P.J. & Jordan, G.J. (2003) A species list for the bryophytes and ferns occurring as epiphytes on Tasmanian tree ferns. *Hikobia* 14: 25–31.

Roberts, N.R., Dalton P.J. & Jordan, G.J. (2005) Epiphytic ferns and bryophytes of Tasmanian tree-ferns: A comparison of diversity and composition between two host species. *Austral Ecology* 30: 146–54.

Sattler, P.S. and Williams, R.D. (Eds) 1999, *The Conservation Status of Queensland Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.

Scarlett, N.H. (1980) A register of rare and endangered native plant species in Victoria. Department of Botany, Latrobe University unpublished.

Smale, M.C., Burns, B.R., Smale P.N. & Whaley, P.T. (1997). Dynamics of upland podocarp/broadleaved forest on Mamaku Plateau, central North Island, New Zealand. *Journal of the Royal Society of New Zealand* 27(4): 513–532

Smith, A.R. & Grayum, M.H. (1988) *Cyathea stolzei* x *ursine*, a distinctive tree fern hybrid from Costa Rica. *American Fern Journal* 78(3): 105–108.

Sokal, R.R. & Michener, C.D. (1958) A Statistical Method for Evaluating Systematic Relationships. *The University of Kansas Scientific Bulletin* 38: 1409–1438.

Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section (2011a) *Listing Statement for* Cyathea cunninghamii *(slender treefern).*

http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LJEM-6UN3FS/$FILE/Cyathea%20cunninghamii%20LS.pdf

Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania. Threatened Species Section (2011b) *Listing Statement for* Cyathea *x* marcescens *(skirted treefern).* http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LJEM-76XVTA/$FILE/Cyathea%20Xmarcescens%20LS.pdf

Tasmanian Department of Primary Industries, Parks, Water & Environment, Tasmania Threatened Species Section (2011c) *Flora Recovery Plan: Threatened Tasmanian Ferns*. Department of Primary Industries, Parks, Water & Environment, Hobart http://www.environment.gov.au/biodiversity/threatened/publications/recovery/pubs/threatened-tasmanian-ferns.pdf

Threatened Species Protection Act 1995 Native Plants and Animals. Threatened species list. http://www.dpiw.tas.gov.au/inter.nsf/WebPages/SLEN-5P37UP?open#C

Threatened Species Conservation Act 1995 http://www.environment.nsw.gov.au/threatenedspecies/tscategories.htm

Unwin, G.L. & Hunt, M.A. (1996) Conservation and management of soft tree fern *Dicksonia antarctica* in relation to commercial forestry and horticulture. In Camus, J.M., Gibby, M. & Johns, R.J. (Eds) *Pteridology in Perspective*, Royal Botanic Gardens, Kew, pp. 125–137.

Unwin, G.L & Hunt, M.A. (1997) Regeneration biology and silviculture of Tasmanian Soft Tree Fern *Dicksonia antarctica*. Australian Flora Foundation Final Report 1997. http://www.aff.org.au/Unwin_Dicksonia_final.pdf

Victorian Department of Sustainability & Environment (undated). Draft Flora & Fauna Guarantee Action Statement Slender Tree-fern *Cyathea cunninghamii* (Including references to the Skirted Tree-fern *Cyathea* x *marcescens*).

Victorian Scientific Advisory Committee (1992) Final Recommendation on a nomination for listing: Slender Tree-fern *Cyathea cunninghamii* (Nomination No. 191). Scientific Advisory Committee, Flora and Fauna Guarantee. Department of Natural Resources & Environment: Melbourne.

Volkova, L., Bennett, L.T., Merchant, A. & Tausz, M. (2010a) Shade does not ameliorate drought effects on the tree fern species *Dicksonia antarctica* and *Cyathea australis*. *Trees-Structure and Function*, 24: 351–362.

Volkova, L, Bennett, L.T. & Tausz, M. (2010b) Diurnal and seasonal variations in photosynthetic and morphological traits of the tree ferns *Dicksonia antarctica* (Dicksoniaceae) and *Cyathea australis* (Cyatheaceae) in wet sclerophyll forests of Australia. *Environmental & Experimental Biology* 70(1): 11–19.

Volkova, L., Bennett, L.T. & Tausz, M. (2010c) Effects of sudden exposure to high light levels on two tree fern species *Dicksonia antarctica* (Dicksoniaceae) and *Cyathea australis* (Cyatheaceae) acclimated to different light intensities. *Australian Journal of Botany* 57(7): 562–571.

Volkova, L., Tausz, M., Bennett, L.T. & Dreyer, E. (2009) Interactive effects of high irradiance and moderate heat on photosynthesis, pigments, and tocopherol in the tree-fern *Dicksonia antarctica. Functional Plant Biology* 36(12): 1046–1056.

Walker, J. & Tunstall, B. R. *Field estimation of foliage cover in Australian woody vegetation.* Technical Memorandum 81/91. CSIRO Institute of Biological Sciences, Canberra.

Wagner, W.H. & Wagner, F.S. (1986) Detecting abortive spores in herbarium specimens of sterile hybrids. *American Fern Journal* 76(3): 129–140.

Wakefield, N.A. (1942) A new species of *Cyathea*. *The Victorian Naturalist* 59: 33–34.

Wakefield, N.A. (1945) Additions to the Victorian Pteridophyta. *The Victorian Naturalist* 62: 125–126.

Wakefield, N.A. (1953) Alfred National Park an East Gippsland National Reserve. *The Victorian Naturalist* 70: 12–15.

Wakefield, N.A. (1967) *Naturalists Diary*. Longmans. Croydon, Melbourne.

Wakefield, N.A. 1975. Ferns of Victoria and Tasmania. *Field Nationalists Club of Victoria, Melbourne.* 84pp.

Wakefield, N.A. & Willis, J.H. (1949) Victorian Fern and Clubmoss Records – 1. *The Victorian Naturalist* 65: 215-217.

Walsh, N.G., & Entwisle, T.J. (1994). *Flora of Victoria,* Volume 2. Inkata Press, Melbourne.

Walsh, N.G. & Stajsic, V. (2007) *A Census of the Vascular Plants of Victoria.* National Herbarium of Victoria, Royal Botanic Gardens, South Yarra, Victoria. Eighth Edition.

Wardlaw, A.C. (1997) Tree-ferns in south-eastern Australia and New Zealand: a tourist's view. *Pteridologist* 3(2):92–96.

Willis, J.H. (1970) *A Handbook to Plants in Victoria.* Volume 1. Melbourne University Press, Carlton.

Wishart, D. (1969) An algorithm for hierarchical classifications. *Biometrics* 25: 165–170.

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Appendix 1 Summary of floristic and habitat information for six vegetation communities (groups) with which tree ferns *Cyathea cunninghamii* and *Cyathea* x *marcescens* are associated. *Cyathea cunninghamii* was recorded in all six vegetation communities; *Cyathea* x *marcescens* was recorded in two: Group 1 and Group 6.

	No. of Sites	Distribution	Altitude m (mean, se)	Slope, aspect	Landform	Mean species richness per plot (0.09 ha)	Dominant Species
Group 1							
Wet sclerophyll Forests and Fern gullies **Includes:** *C. cunninghamii* *C. australis* *C.* x *marcescens*	20	**Victoria:** Otway Ranges, South, Central and East Gippsland, Yarra Ranges, Badgers Creek Healesville	373 (27)	gentle to steep slopes, southerly aspect	Creeks and minor river banks	25	**Trees:** *Eucalyptus fastigiata*, *E. regnans*, *Nothofagus cunninghamii* **Small Trees:** *Acacia melanoxylon*, *Atherosperma moschatum*, **Shrubs:** *Coprosma quadrifida, Dicksonia antarctica* **Ground Cover:** *Lastreopsis acuminata*, *Polystichum proliferum*
Group 2							
Warm and Cool Temperate overlap Rainforest **Includes:** *C. cunninghamii* *C. australis* *C.* x *marcescens*	8	**Victoria:** Wilsons Promontory National Park, Errinundra National Park	186	Flat to gentle slopes, nil aspect	Boggy stream terraces, stream confluences	35	**Trees:** *Acmena smithii, Atherosperma moschatum, Eucalyptus obliqua, Nothofagus cunninghamii* **Small Trees:** *Acacia melanoxylon, Pomaderris aspera* **Shrubs:** *Coprosma quadrifida, Dicksonia antarctica, Zieria arborescens* subsp. *arborescens* **Ground Cover:** *Lepidosperma elatius Pellaea falcata* s.l., *Polystichum proliferum*
Group 3							
Cool Temperate Rainforest **Includes:** *C. cunninghamii* *C. australis* *C.* x *marcescens*	67	**Victoria:** Otway Ranges, South Gippsland Tarra-Bulga National Park	287	Moderate to steep slopes, southerly aspect	Streams in headwaters of minor catchments	25	**Trees:** *Atherosperma moschatum, Nothofagus cunninghamii* **Small Trees:** *Acacia melanoxylon, Pittosporum bicolour* **Shrubs:** *Dicksonia antarctica, Hedycarya angustifolia* **Groundcover:** *Blechnum wattsii, Polystichum proliferum*
Group 4							
Lowland Wet Sclerophyll Forest **Includes:** *C. cunninghamii*	4	**Victoria:** Wilsons Promontory National Park **Tasmania:** Eaglehawk Neck, Hastings Caves	72	Gentle slopes, nil aspect	Minor gullies	26	**Trees:** *Eucalyptus obliqua, Nothofagus cunninghamii* **Small Trees:** *Acacia melanoxylon, Bedfordia salicina, Olearia argophylla, Pomaderris apetala* **Shrubs:** *Tasmannia lanceolata* **Ground Cover:** *Blechnum wattsii Polystichum proliferum,*

Group 5						
Lowland Damp Sclerophyll Forest and Rainforest Ecotones **Includes:** *C. cunninghamii* *C. australis* *C.* x *marcescens*	8	**Victoria:** East Gippsland Croajingalong National Park Mt Drummer Alfred National Park	267	Moderate slopes, variable aspects incised gullies	Moderate to deeply	50	**Trees:** *Acmena smithii, Eucalyptus cypellocarpa* **Small Trees:** *Pomaderris aspera, Rapanea howittiana* **Shrubs:** *Bedfordia arborescens, Cyathea australis* **Ground Cover:** *Blechnum cartilagineum, Lastreopsis acuminata*
Group 6						
Mid-elevation Damp Sclerophyll Forest and Rainforest Ecotones **Includes:** *C. cunninghamii* *C.australis* *C.* x *marcescens*	5	**Victoria:** East Gippsland Errinundra National Park (Goolengook) **New South Wales:** Maxwell Flora Reserve Nadgee State Forest	348	Moderate slopes, variable aspects	Minor headwater gullies	27	**Trees:** *Acmena smithii, Eucalyptus fastigata, Eucryphia moorei* **Small Trees:** *Acacia melanoxylon, Pomaderris aspera* **Shrubs:** *Cyathea australis, Rubus moluccanus* var. *trilobus* **Ground Cover:** *Blechnum patersonii, Lastreopsis acuminata*

Appendix 2 Relative percent abundance of species present in each of six vegetation groups, expressed as the average abundance of a given species in a given group of plots over the average abundance of that species in all plots (following Dufrêne & Legendre, 1997).

Group 1 Wet Sclerophyll Forests and Fern gullies; Group 2 Warm and Cool Temperate Overlap Rainforest; Group 3 Cool Temperate Rainforest; Group 4 Lowland Wet Sclerophyll Forest; Group 5 Lowland Damp Sclerophyll Forest and Rainforest Ecotones; and Group 6 Mid-elevation Damp Sclerophyll Forest and Rainforest Ecotones

The p value indicates the significance of the species maximum indicator value following a Monte Carlo randomisation test. * indicates introduced species

Taxon	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**p value**
Acacia cognata					100		
Acacia dealbata	52		48				
Acacia frigescens	100						
Acacia melanoxylon	11	28	16	22	22	1	
**Acer pseudoplatanus*	100						
Acmena smithii		30			56	13	0.0014
**Anthoxanthum odoratum*			100				
Asplenium appendiculatum subsp. *appendiculatum*				88	12		
Asplenium bulbiferum subsp. *gracillimum*	10	16	16	4	27	27	
Asplenium flaccidum subsp. *flaccidum*			75		25		0.0070
Atherosperma moschatum	15	38	30	17			
Austrocynoglossum latifolium			100				
Australina pusilla subsp. *muelleri*	28	6	24		17	25	
Bedfordia arborescens	5	31			61	3	0.0104
Bedfordia salicina				100			0.0012
Blechnum cartilagineum					98	2	0.0001
Blechnum chambersii	6	22	48	18	1	4	0.0245
Blechnum fluviatile	27	6	55	12			0.0223
Blechnum minus	100						
Blechnum nudum	4	2	13	67	13	2	0.0058
Blechnum patersonii subsp. *patersonii*	15	17	4		30	35	0.0476
Blechnum wattsii	3	15	42	23	17		0.0129
Calochlaena dubia		81			19		
Cardamine hirsuta	100						
Carex appressa	20	33	37			10	
Cassinia aculeata					100		
Cassinia longifolia	100						
Cassinia trinerva	12	8	8		59	13	0.0363
Celastrus australis					100		0.0058
**Cephalomanes caudatum*		12			88		0.0115
Cissus hypoglauca	2				89	9	0.0001
Clematis aristata	19	46	12	18	6		0.0213
Clematis glycinoides var. *glycinoides*	8				77	15	0.0024
Coprosma quadrifida	10	38	18	10	21	3	0.0411
Correa lawrenceana var. *latrobeana*			3		97		0.0003
Crepidomanes venosum	7	40	18	7	18	11	
Ctenopteris heterophylla	6	32	30	32			
Cyathea australis	13	9	3		63	13	0.0022
Cyathea cunninghamii	10	17	22	17	20	14	
Cyathea leichhardtiana					100		
Cyathea x *marcescens*	31	6	17		6	39	0.0312
**Dactylis glomerata*	100						
Dianella tasmanica	32		6		62		
Dicksonia antarctica	19	18	29	9	18	6	0.0001
Diplazium australe	6		27		46	21	0.0235
Elaeocarpus reticulatus		23		10	49	17	0.0249
Eucalyptus cypellocarpa	32	11			58		0.034
Eucalyptus fastigata	14				52	34	
Eucalyptus obliqua		10		88	2		0.001
Eucalyptus regnans	44	49	3	5			
Eucalyptus smithii					100		
Euchiton collinus			100				
Eucryphia moorei					100		
Eupomatia laurina					100		
Eustrephus latifolius		6			94		0.0001

Fieldia australis	14	27	6	1	40	11	0.0219
Gahnia clarkei		5	2		93		0.0118
Gahnia melanocarpa					88	12	0.0001
Gahnia sieberiana					100		
Geitonoplesium cymosum					100		
Gnaphalium spp.			100				
Goodia lotifolia					100		
Goodenia ovata			100				
Grammitis billardierei	11	30	31	16	9	3	
**Hedera helix*	100						
Hedycarya angustifolia	20	7	48		18	7	0.0043
Histiopteris incisa	18	11	13	33	18	6	
**Holcus lanatus*			100				
**Huperzia varia*			100				
Hydrocotyle hirta	13	16	54		16		
Hymenophyllum australe	8	20	65	4	2		0.0003
Hymenophyllum cupressiforme	8	9	31	16	27	9	
Hymenophyllum flabellatum	20	20	42	18			0.0598
Hymenophyllum rarum	8	17	42	34			
**Hypericum androsaemum*			44		56		
Hypolepis muelleri					100		
Hypolepis rugosula	18		18	51	13		
**Ilex aquifolium*	100						
Isolepis fluitans	100						
Isolepis inundata	5	12	36	24	24		
Juncus pauciflorus			100				
Lastreopsis acuminata	5	10	23	1	40	21	0.049
Lastreopsis hispida			100				
Lepidosperma elatius	9	42	1	47			
Lepidosperma laterale		67			33		
Lobelia pedunculata s.l.			100				
Lomatia fraseri	9	53	14	24			
**Lonicera japonica*	100						
Macroglena caudata		17			83		
Marsdenia rostrata	1				95	4	0.0001
Microsorum pustulatum subsp. *pustulatum*	7	67	15	5	5		0.0001
Microsorum scandens	1	31			54	13	0.0016
Morinda jasminoides					87	13	0.0005
Notelaea ligustrina	9	11	59	22			
Notelaea venosa		11			89		0.0005
Nothofagus cunninghamii	4	11	85	1			0.0001
Olearia argophylla	15	18	8	30	26	3	
Olearia lirata	13	16	14		56		
Oplismenus hirtellus					100		
Pandorea pandorana	5	44		5	31	15	
Parsonsia brownii	8	26	8	6	39	13	
Pellaea falcata s.l.		53	2		44		0.0544
Pittosporum bicolor	11	23	30	33		3	
Pittosporum undulatum		1			99		0.0001
Plantago debilis					100		
Poa ensiformis					100		
Poa labillardierei var. *labillardierei*			100				
Polyscias murrayi					100		
Polystichum proliferum	19	6	13	43	15	5	
Pomaderris apetala				100			0.0001
Pomaderris aspera	28	24		1	42	4	0.0424
Prostanthera lasianthos var. *lasianthos*	12		15		73		0.0495
Prostanthera melissifolia					100		
Pteridium esculentum	10	55			35		0.0346
Pteris tremula					100		
Pteris umbrosa					100		0.0001
Pyrrosia rupestris					88	12	0.0003
Rapanea howittiana		4	1		88	7	0.0211
**Rubus fruticosus* agg.	31		18		51		
Rubus moluccanus var. *trilobus*	3				63	34	0.0026
Rubus parvifolius					100		
Rubus rosifolius var. *rosifolius*	3				70	26	0.0122
Rumohra adiantiformis	16	9	28	19	13	15	
Sambucus gaudichaudiana	28	32	11		29		
Sarcopetalum harveyanum					89	11	0.0002
Schoenus maschalinus					100		

Senecio minimus			11		89		
Senecio spp.	77		23				
Smilax australis	1	4			93	3	0.0001
Stellaria flaccida	43	6	9		22	20	
Sticherus lobatus		57	1		41		0.0157
Sticherus tener s.l.		29	71				
Tasmannia lanceolata	8		7	66	19		0.0202
Tetrarrhena juncea	23	11	3	11	52		0.032
Tmesipteris obliqua	6	13	6	6	64	5	
Tmesipteris ovata					100		0.0113
Tmesipteris parva	3	22			63	12	0.0226
Todea barbara		11	5	79	5		
**Tradescantia fluminensis*	100						
Tristaniopsis laurina					100		
Tylophora barbata					100		0.0003
Uncinia nemoralis			100				
Uncinia tenella	6	29	43	10	12		
Urtica incisa	12	17	28	11	31		
Viola hederacea	4	14	4	5	58	15	0.0078
Viola odorata	100						
**Watsonia meriana*	100						
Zieria arborescens subsp. *arborescens*		80	1	19			0.0064

Appendix 3 The threat status of *Cyathea cunninghamii* and *Cyathea* x *marcescens* according to National and various State Legislations

	Cyathea cunninghamii	***Cyathea* x *marcescens***
National		
Rare or Threatened Australian Plants (Briggs and Leigh 1996)	rare	not listed
ANZECC Threatened Australian Flora list (1999)	rare	not listed
Environment Protection and Biodiversity Conservation Act (1999)	not listed	not listed
New South Wales		
Threatened Species Conservation Act (1995)	not listed	outside distribution
Victoria		
Department of Sustainability and Environment (2005) Advisory List of Rare or Threatened Plants in Victoria (2005)	vulnerable	threatened
Flora and Fauna Guarantee Act 1988 Section 10 (2012)	vulnerable	outside criteria (sterile hybrid)
Tasmania		
Flora Advisory Committee (1994)	rare	endangered
Threatened Species Protection Act (1995)	not listed	endangered
Queensland		
Nature Conservation Act (1992)	near threatened	outside distribution