ECOLOGICAL OBSERVATIONS ON A REMOTE MONTANE OCCURRENCE OF *BEDFORDIA ARBORESCENS* (ASTERACEAE), CAPE BARREN ISLAND, TASMANIA

by Stephen Harris and Eve Lazarus

(with six plates, six text-figures, three tables and one appendix)

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Bedfordia arborescens Hochr. is a tree listed under the Tasmanian *Threatened Species Protection Act 1995* and is known in Tasmania only from an outlying population in cloud forest on Mt Munro, Cape Barren Island in the Furneaux Group. While the species is a common component of some rainforest and mixed forest in southeast mainland Australia, the outlying population on Cape Barren Island has apparently been eroded by a high fire frequency over the previous 200 years. The species occupies an ecological zone that is marginal to *Atherosperma moschatum* Labill.-dominated rainforest. Some stands occur adjacent to grasslands separated by a sharp ecological boundary. Even-aged cohorts represent the population structure on the mountain with no evidence of recent regeneration in or adjacent to any particular stand. A range of different aged cohorts occurs within the forest across the mountain. Mt Munro intercepts cloud moisture, resulting in the development of a cloud forest and a steep precipitation gradient between Mt Munro and the nearby coast. The persistence of *B. arborescens* on Mr Munro can be attributed partly to the sharp topographical boundaries that have been reinforced by fire due to the burning frequency on the mountain. The vegetation patterning has responded to frequent anthropogenic fires during the past 200 years. Comparisons are made with subalpine grasslands in New Guinea and elsewhere. Future fire management on Cape Barren Island will be critical to the survival of *B. arborescens* in Tasmania. On the basis of modified IUCN criteria used in Tasmania for listing of threatened species, it is recommended that the status *of B. arborescens* be up-listed from rare to vulnerable.

Key Words: Aboriginal land management, Bass Strait, *Bedfordia arborescens*, Cape Barren Island, conservation statns, forest, fire, flora, human impact, Mt Munro, palaeogeography, relict vegetation, temperate cloud forest, threatened species, tree Asteraceae.

INTRODUCTION

Bedfordia arborescens Hochr. or blanketleaf, is in the family Asteraceae, most of which are herbs and shrubs, comprising approximately 25 000 species worldwide. This species is one of the few trees in the family (Heywood 1985).

The taxonomy and distribution of *Bedfordia* species is well known. *B. arborescens* is one of three *Bedfordia* species within Australia (Orchard 2004). *B. salicina* is allopatric with *B. arborescens* (fig. 1). Only *B. linearis* ssp. *linearis* overlaps the range of *B. arborescens* because it has been recorded from Flinders Island (Australian Virtual Herbarium, accessed 27 March 2005). *B. arborescens* is largely a mainland Australian tree while the other two species are endemic in Tasmania. A revision of *Bedfordia* (Orchard 2004) resulted in new subspecific taxa within *B. linearis*. Two key differences between *B. arborescens* and *B. salicina* were defined, namely the ventral leaf hairs on *B. arborescens* occur in two distinct layers in contrast to the single layer in *B. salicina*, and in *B. arborescens* the hairs on the outer layer are floccose and thickened at the base, whereas the hairs on *B. salicina* are clearly appressed or matted and not thickened at the base. *B. arborescens* occurs in wet eucalypt forest, mixed forest, warm temperate rainforest and dry rainforest in southeastern Australia, from Braidwood in New South Wales to southern coastal Victoria (Costermans 1983, Peel 1999). *B. arborescens* in Victorian forests occurs mainly in gullies (Dr D. Ashton, pers. comm.).

B. arborescens was first collected in Tasmania from Mt Munro, the outlying, southernmost extent of its range on 7 October 1988 (voucher specimen: HO114565). Although Robert Brown recorded *Senecio arborescens* on Mt Wellington near Hobart, Vallance *et al.* (2001) claimed this was probably *B. arborescens* Hochr. It is most likely to be *B. salicina*. We note that Brown also recorded *Seneciastrum arborescens* from Mt Wellington, but this is the closely-related (Orchard 2004), large, woody Asteraceae, now known as *Brachyglottis brunonis*. To our knowledge no *B. arborescens* has been collected on Mt Wellington, or at any other Tasmanian location apart from Mt Munro.

On mainland Australia, the tree is common and is not considered to be a threatened species. However, *B. arborescens* was listed as rare in Tasmania due to its localised distribution on Cape Barren Island.

Victorian studies indicate that *B. arborescens* is adapted to periodic fire disturbance. Ashton (1981, 2000a, b) described the relationship between time since last fire, topography, and understorey type, in *Eucalyptus regnans* forests in central Victoria. *B. arborescens* occurs in mixed forest with *N. cunninghamii* and *Atherosperma moschatum* understorey that was last burnt in 1898, and in *E. regnans* forest with an understorey comprising *Bedfordia* that was last burnt in 1926. No studies are known to us that have focused on *B. arborescens*, and certainly no work has been published on the species or its habitat in Tasmania.

Cape Barren Island, comprising 462 square kilometres, is the second largest island in the Furneaux Group, and Mt Munro, rising to 687 m in the northwestern corner of the island, is its highest peak (fig. 2).

The aims of the present study are to gather information that will assist in understanding and managing *B. arborescens*, and to reassess its Tasmanian conservation status. This is the first published record of botanical exploration on Mt Munro.

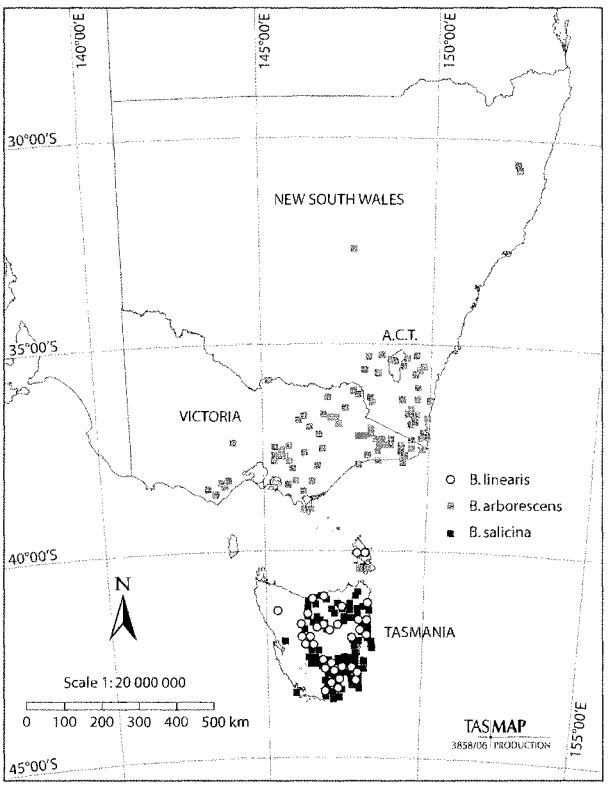

FIG. 1 — Distribution of Bedfordia *species compiled from Australian Virtual Herbarium data (March 2005).*

METHODS

This study is based on two visits to the island, in January and April 2004 during which fieldwork on foot was conducted to ground truth the vegetation map, to make notes on plots located at various sites on the mountain and to record observations on a transect across a vegetation boundary.

Description of the Study Area

Information on the geology, soils and climate was synthesised from various published and unpublished sources and field observations, to provide an environmental context for our study. This was supplemented by aerial photograph interpretation of landforms and field observations. Data collected from plots included information on environmental parameters (see population biology).

BIOCLIM modelling (Busby 1991) was used to develop a rainfall model for the Furneaux Group. BIOCLIM modelling develops a predictive surface for 27 climatic parameters encompassing temperature, precipitation and radiation variables (K. Bossard, pers. comm.) It is considered to have a high veracity for accurate rainfall predictions, and we used it to help define the environmental envelope for *B. arborescens* as well as highlight potential habitat that could be searched for the species. Some characteristics of the climate were described from field observations. BIOCLIM was run using three different sets of data combinations: Cape Barren *B. arborescens* records only; Cape Barren and/or mainland Australian records and mainland Australian records alone.

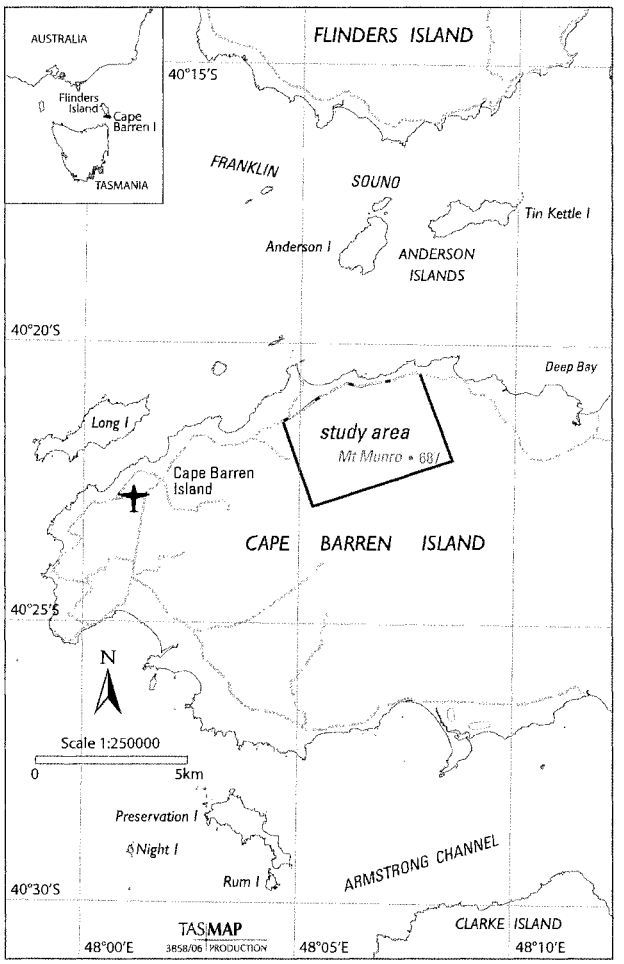

FIG. 2 — Location of study area, Cape Barren Island, Tasmania.

The Vegetation

Photo-communities were mapped from full-colour 1:42 000 scale aerial photographs dated 15 November 2003. These photo-communities were checked in the field, and where possible were allocated to TASVEG State-wide mapping communities (nomenclature follows Harris & Kitchener 2005) using species information from 33 plots of 10 m x 10 m.

One transect was laid down perpendicular to sharp grassland forest boundaries. The transect was 1100 m long and comprised 10 m x 10 m plots, spaced ten metres apart, six plots in all. Species presence and estimated absolute percentage cover values were recorded. The information from this transect was then diagrammatically illustrated. A vegetation profile was prepared to show the major changes from the coastal plain to the summit of Mt Munro. Observations along routes accessed by foot were used to supplement information from 10 m x 10 m plots located across the study area.

Historical information on the vegetation and impacts upon it were collected from published and unpublished sources. This was supplemented by an examination of earlier black and white aerial photographs dating from 14 January 1968 and 8 January 1980.

The Flora

Voucher specimens of most species observed were lodged in the Tasmanian Herbarium (HO). A search of the National Herbarium of Victoria (MEL), and the National Herbarium of New South Wales (NSW) was made for plant species collected from the island. A complete inventory of species from the mountain was not attempted.

Plant nomenclature follows Buchanan (2005) for vascular species except where authorities are given.

No systematic examination of non-vascular flora has been carried out, although some collections of lichens exist in the National Herbarium of Victoria. The cryptogamic flora is certain to be of great biogeographic interest and will repay closer scrutiny.

Population Biology and Autecology of *Bedfordia arborescens*

Location of the plots was according to the "subjective without preconceived bias" approach of Mueller-Dombois and Ellenberg (1974, p.32). Species presence, vegetation structure, soil pH measured with a CSIRO field testing kit (Inoculo Laboratories), rock type, fire history and geographical features such as aspect, altitude, topography, drainage and grid reference, were recorded for each plot. Indicators of fire history included counts of growth nodes on *Banksia marginata*, ring counts on sectioned *Leptospermum* spp., presence of fire-killed stags, downers and stems with charcoal remnants. Topographical and geomorphological features were noted from field observations and from air photo interpretation.

Girth measurements of as many specimens as time allowed were obtained with a diameter tape at breast height (1.5 m above the ground).

General observation on the habit and response of *B. arborescens* to physical damage from storms or from other limbs falling on them, and observations on historical disturbance events such as fires, were noted.

Conservation and Reservation Status

Herbarium data from the National Herbarium of Victoria (MEL) and the Tasmanian Herbarium (HO) were examined to check whether *B. arborescens* had been collected elsewhere in the region, particularly in areas that were predicted by the BIOCLIM model to be potential sites.

The authors surveyed suitable cloud forest habitat on the Strzelecki Range (Flinders Island) in September 2004.

The conservation status of *B. arborescens* was reviewed using the conservation status assessment database (Threatened Species Section, Department of Primary Industries and Water), which is based on IUCN red list categories (IUCN 1994) and modified explanatory criteria for Australian plants. The conservation and reservation status of species and communities were assessed against published lists, including the Schedules to the Tasmanian *Threatened Species Protection Act 1995*.

RESULTS

Geology, Soils and Climate

Mt Munro has numerous ridges and gullies dissecting its flanks and a plateau beneath the ultimate peak. Bedrock is prominently exposed as large slabs, tors and boulder-fields. Examples of granite-weathering phenomena such as tafoni, gnamma pits, exfoliation weathering and perched boulders occur. All of the subject area is vegetated including the apparently bare rock, which is invariably occupied by lichen-field. Some steep gullies occur as well as waterfalls, small cliffs and a small tarn. Drainage lines are incised and dendritic stream headwaters occur around the mountain. Much of the drainage from Mt Munro is to the southwest by the Modder River.

Mt Munro comprises granites similar in texture and composition to those on Wilson's Promontory and northeastern Tasmania (Burrett & Martin 1989). The soils derived from these are acid sandy loams, sometimes underlain by clay in gully sites and valley bottoms. On slopes and ridges soil is skeletal and of highly-variable depth (Pinkard & Richley 1982). In crevices, for example, soil may be more than 0.5 m deep whereas at other sites, the soil may comprise only thin accumulations of felspar and quartzite fragments.

Nowhere on the mountain, except on the floor of the deep gullies, did we observe a well-developed humic soil horizon of any note. The pH on the grassland soils was measured as 5.0–5.5 in one locality while in the forest the pH was measured as 6.0 at two sites.

Around the base of Mt Munro, there are some remnant deposits of Tertiary limestone (calcarenite) which weathers to loamy alkaline soils. In most instances the remnant calcarenite has been obscured around the base of Mt Munro by aprons of acid colluvial deposits derived from granite weathering.

Cape Barren Island is in the warm humid zone (Gentilli 1972). Although there are no meteorological stations on the island the figures for the nearest meteorological station (Bureau of Meteorology website) at Flinders Island airport 36 km to the north are used as indicative of the climate at the coast adjacent to Mt Munro. Rain falls throughout the year, with a monthly maximum of more than 219 mm in July and a minimum of 130 mm in February. The temperature is mild throughout the year with daily average temperature ranges of 13.6–22.6 °C in February and 6.2–13.3 °C in July (Bureau of Meteorology 1996). The west coast of the island, only 12 kilometres west of Mt Munro, receives the full impact of the westerly swells coming through Bass Strait.

BIOCLIM modelling indicated the rainfall on Mt Munro as 1047 mm annual average while on the coast at The Corner it is of the order of 500–600 mm annual average. There would be less evapotranspiration at the higher altitude because of the frequency of cloud capping.

B. arborescens occurs in a montane environment above 350 m altitude. Orographic precipitation from the westerly airstream is significant, and mist and cloud envelops the mountain for many days in the year, even in summer (SH unpublished data). Under certain conditions, easterly airstreams also result in dense cloud cover of the mountain. Moisture is stripped from the cloud by the vegetation.

Historical Accounts of Vegetation and Habitat

Records of vegetation character prior to the main period of human occupation in about the 1840s, are sparse, tantalising and only hint at a more extensive forest cover than exists today.

Collins (1798–1802: 152) observed from the southern side, that on Cape Barren Island: "The high part is composed of granite, in many places almost bare, in others poorly clothed with moderate sized gum trees, which draw their support through some small quantity of vegetable earth lodged by the broken blocks and fragments of the stone, and some struggling brush-wood shooting up round the trees, and completing the appearance of a continued vegetation. The base of the low part...chiefly sand, its produce, variety of brush, with some few small gum trees, and a species of fir, that grows tall and straight to the height of 20 or 25 feet".

Flinders noted in 1798 that all the islands "are over–run with brush wood; amongst which, in the more sheltered and less barren parts, are mixed a few stunted trees, which seem to shed their bark annually, and to be of the heavy kind called gum tree...". "The brush wood is commonly impenetrable..." (Flinders 1814: 132–133).

Campbell (1828: 1) reported of Cape Barren Island: "...the whole island is well wooded, the trees being the same as those generally found in Van Diemen's Land, pine trees of a small size grow here, but in no great quantities. The surface is generally covered with a thick brush, excepting on some of the barren heights where the grass tree is found...".

Backhouse & Walker (cited in Plomley 1966: 258) reported their observations from 1832: "The lofty parts of Flinders and Cape Barren are very sterile, but many of the lower hills are covered with timber of a tolerable size, chiefly blue gum. The valleys and lower grounds are, in various places, covered with tall scrub mixed with a species of *Casuarina* differing from the sheoak, and from other trees of the same genus known in the southern parts of Van Diemen's Land, but producing good small timber. The white gum is also met with. The open grassy parts of these islands are not numerous...".

Howard (1991: 85) quoted Archdeacon Reiby who observed in March 1862: "An extensive fire had been raging through and over the island, and was not quite extinguished while we went there...".

With human inhabitants on many of the large islands, the likely scenario is an increase in fire frequency (Harris & McKenny 1999, Harris *et al.* 2001). Further field evidence or historical investigation would be valuable for exploring fire history in more detail.

Many observations and reports of fires on Cape Barren Island in the past 150 years (Senior Ranger Chris Arthur, pers. comm.) indicate consequent changes in vegetation patterning and flora composition.

Description of Vegetation Communities in the Study Area

Ten vegetation communities have been mapped in the study area (figs 3, 4). The principal characteristics and species recorded in these communities are listed in table 1. Brief notes on each vegetation community are in Appendix 1.

The *Bedfordia arborescens* Community

B. arborescens occurs in rainforest with floristic similarities to the Callidendrous Sassafras-musk relict rainforest dominated by *Atherosperma moschatum* that has been described for northeastern Tasmania (Neyland & Brown 1993) (table 2).

Among co-occurring species with *B. arborescens* on Mt Munro were *Olearia argophylla*, *Pomaderris apetala*, *Pittosporum bicolor*, *Notelaea ligustrina* and *A. moschatum* in the canopy layer. *Dicksonia antarctica* shared the secondary layer with undershrubs including *Pimelea drupacea*, *Bursaria spinosa* and *Coprosma quadrifida*. The ground layer comprised scattered ferns, moss and lichen over granite boulders. Stands in which the tree occurred were generally dense with a closed canopy and often a mid-dense understorey.

The Flora

The species typical of the vegetation types were recorded (e.g., fig. 5)and have been listed above and in Appendix 1.

The flora on the mountain can be expected to have close affinities with that on the Strzelecki Mountains (Harris *et al.* 2005) 15 km north on Flinders Island and to a lesser extent with that on Blue Tier (North *et al.* 1998) in the northeast of Tasmania. *Nothofagus cunninghamii,* which occurs on Blue Tier, is lacking on Mt Munro. Mt Munro would be expected to have lower species richness than on the Strzelecki Mountains following principles of island biogeography theory. No grassland is found on the Strzelecki Mountains, and *B. arborescens* is absent.

Symptoms consistent with *Phytophthora cinnamomi* (Chromista) infection were only observed on the lower slopes of Mt Munro.

In Tasmania, the study area is floristically significant because of its combination of vegetation types. Cape Barren Island has been isolated for perhaps 8000 years and was probably devoid of human influence for at least 4000 years (Sim & Gait 1992). A combination of geographic and palaeo-environmental factors has resulted in some species and species provenances that are of conservation and scientific significance (table 3).

Population Biology of *B. arborescens*

B. arborescens is a long-lived tree producing an annual crop of abundant wind-borne short-lived seeds (pl. 1). All except the longevity are characteristics of the 'r' strategist typical of the Asteraceae. The longevity of the trees indicates a compatibility with a prolonged interval between disturbance events. The minimum interval would be the time required from germination to the first seed-set. This is not directly known from the species but by inference from the estimated fire-free intervals of communities containing *B. arborescens* is thought to be at least ten years. The plant flowers from November to January, and therefore has a short opportunity for seed distribution. If a stand was burnt, there may be no seedling regeneration from the burnt specimens. *B. arborescens* cypselas are strictly wind dispersed and regeneration would require seed from neighbouring unburnt stands. This indicates the need for a minimum population size able to withstand patch burning, and the current distribution pattern of *B. arborescens* on Mt Munro in discrete pockets would assist the

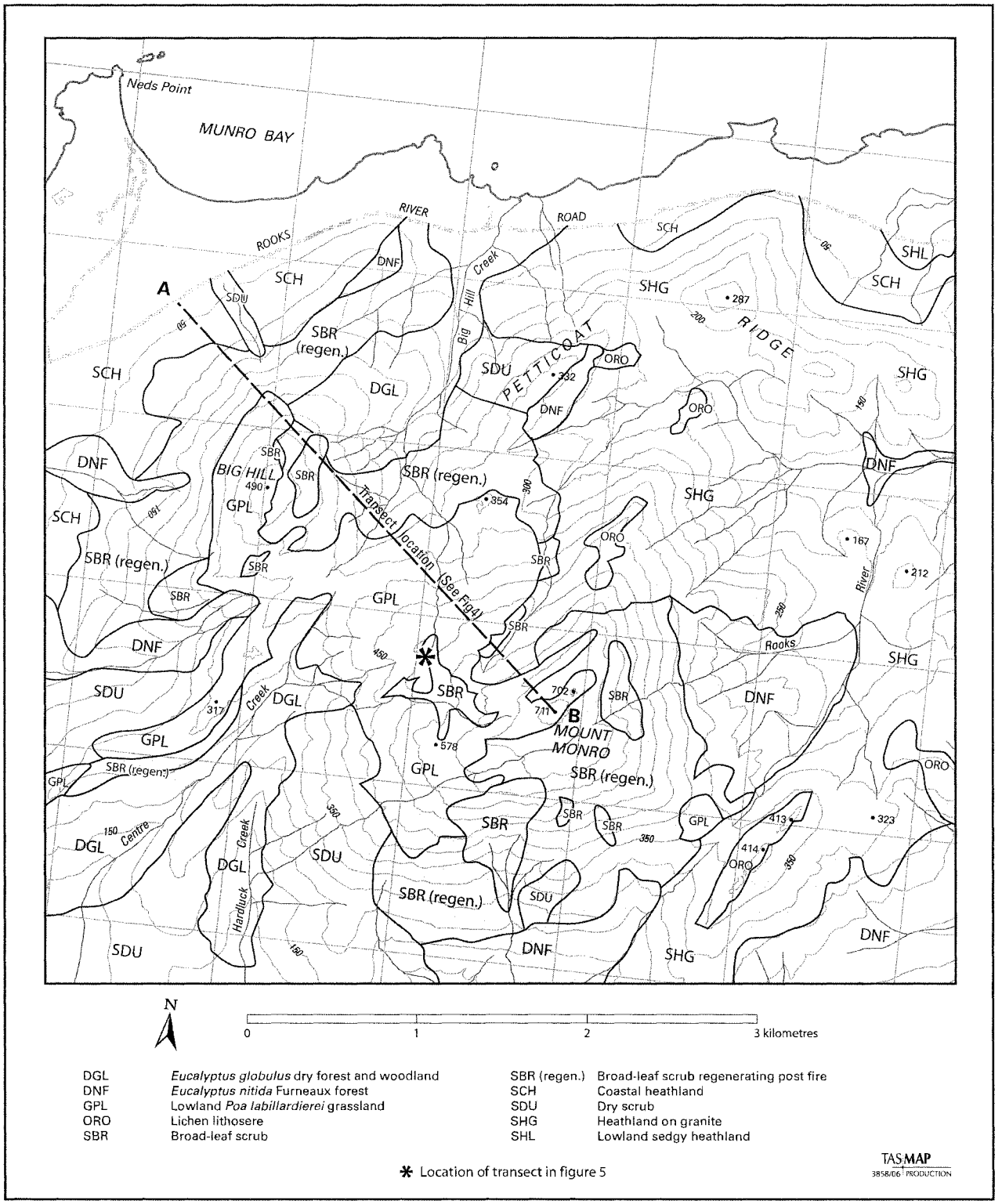

FIG. 3 — Vegetation map of study area.

perpetuation of the species. The nature of the topography on Mt Munro and the fire-protected niches in which this species occurs, prevent a single fire from destroying all the stands. The requirements of the seedlings are not known; however, presumably being highly mesophilous, some nursery crop would be required for shade. If a patch was burned, then some months may pass before seed is deposited in the site. If suitable conditions prevailed, the tree would be replaced at the site.

The relative dominance of *B. arborescens* in different forest patches of possibly varying ages may reflect the diminished cover of the species in older forests. The older forests (or rainforests) are dominated variously by combinations of *O. argophylla, A. moschatum, P. apetala, D. antarctica and B. arborescens*. In the long-term, *B. arborescens* may be a transitory species requiring fire disturbance. The grassland/forest boundary is presently the most obvious vegetation boundary on the mountain, but within the forests there

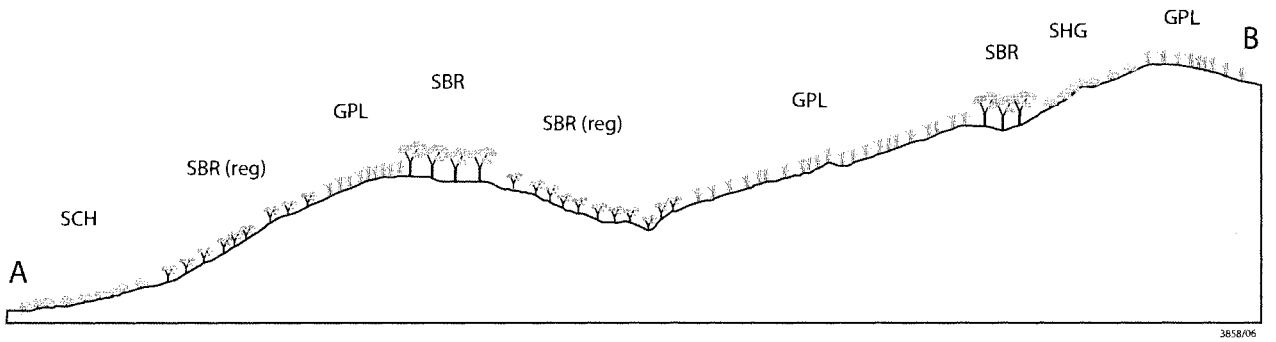

FIG. 4 — Transect diagram showing some major vegetation types in the study area.

TABLE 1
Vegetation types in the study area

Vegetation type	Dominant species	Structure (Specht 1972)	TASVEG
Rainforest and related scrub	*Atherosperma moschatum – Bedfordia arborescens – Olearia argophylla – Pomaderris apetala*	Low closed-forest	Broad-leaf scrub (SBR)
	Zieria arborescens – Gahnia grandis – Goodenia ovata – Pteridium esculentum – Lepidosperma elatius	Closed-scrub	Broad-leaf scrub (SBR) post-fire regeneration
Grassland	*Poa labillardierei – Oxalis perennans – Austrodanthonia* sp.	Closed tussock grassland	Lowland *Poa labillardierei* grassland (GPL)
Eucalypt forest and woodland	*Eucalyptus globulus – Acacia verticillata – Pimelea drupacea – Olearia lirata*	Open-forest	*E. globulus* dry forest and woodland (DGL)
	Eucalyptus nitida – Leptospermum scoparium – Kunzea ambigua	Open-forest	*E. nitida* Furneaux forest (DNF)
Heathland, scrub	*Banksia marginata – Sprengelia incarnata – Acacia* spp. *– Aotus ericoides*	Open-heath	Heathland on granite (SHG)
	Lepidosperma filiforme – Banksia marginata – Lepidosperma concavum – Baumea spp. *– Leptocarpus tenax – Hypolaena fastigiata*	Open-heath	Lowland sedgy heathland (SHL)
	Acacia spp. *– Xanthorrhoea australis – Banksia marginata – Hakea* spp.	Open-heath	Coastal heathland (SCH)
	Eucalyptus nitida – Allocasuarina monilifera – Leptospermum glaucescens – Kunzea ambigua	Open-scrub	Dry scrub (SDU)
Other natural environments	Lichens	Lichen land (in style of Specht)	Lichen lithosere (ORO)

TABLE 2
Nearest-fit vegetation classification for the *Bedfordia arborescens* forest of Mt Munro

Mt Munro cloud forest	TASVEG (Harris & Kitchener 2005)	EVC (Peel 1999)	National Land & Water Resources Audit 2001	Jarman *et al.* 1984	Neyland & Brown 1993
Bedfordia arborescens – Olearia argophylla cloud forest	Broad-leaf scrub (SBR)	Cool Temperate Rainforest	Rainforest & vine thickets (major vegetation group)	Callidendrous Sassafras-musk rainforest (C3.2)	Callidendrous Sassafras-musk rainforest

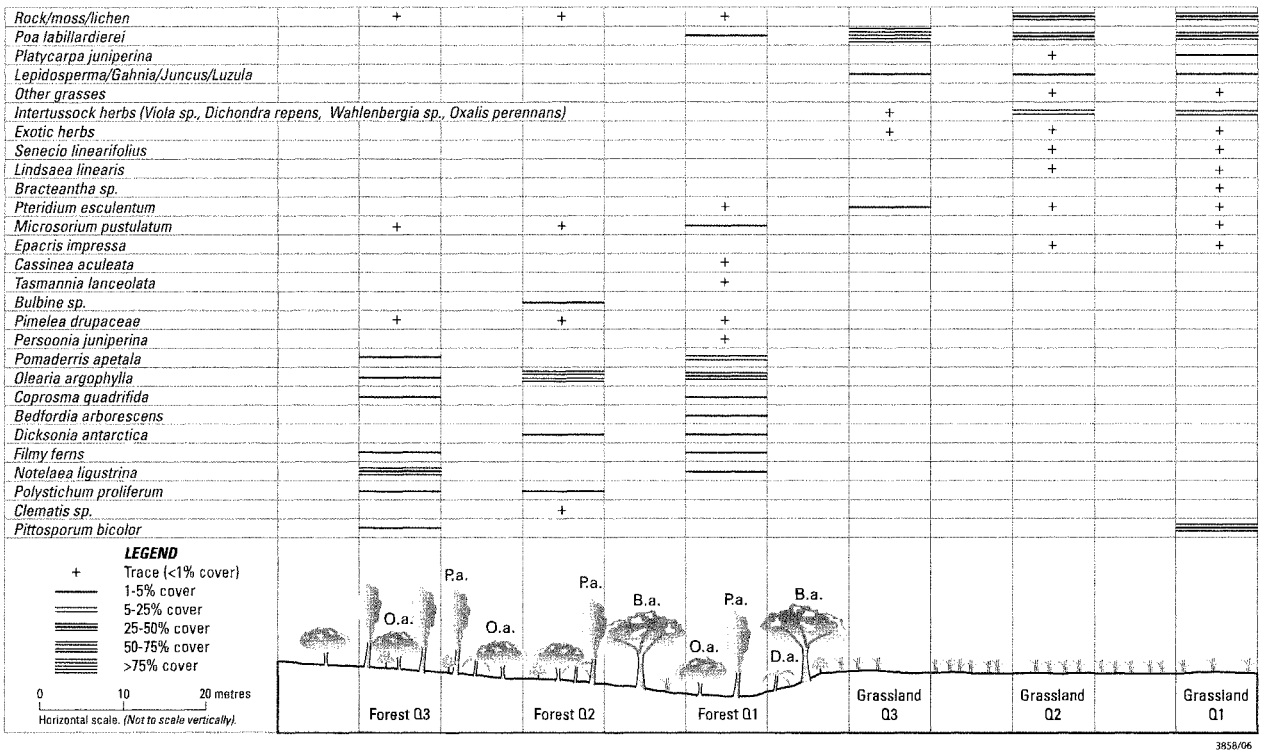

FIG. 5 — Transect diagram of floristic changes across the forest/grassland boundary.

TABLE 3
Species recorded on Mt Munro that are threatened, or are of biogeographic significance

Species	Significance
Atherosperma moschatum	Isolated population.
Bedfordia arborescens	Currently listed as rare under the Tasmanian *Threatened Species Protection Act 1995.*
Conospermum taxifolium	Not listed under the Tasmanian Act but represented by an early collection in the National Herbarium of Victoria and confirmed by Neville Walsh.
Cryptostylis leptochila	Listed as endangered under the Tasmanian *Threatened Species Protection Act 1995.* Discovered on the northeast slopes on Mt Munro, previously only known in Tasmania from Flinders Island.
Eucalyptus globulus	An internationally important silvicultural plantation species with considerable genetic variation, populations isolated on an island are of scientific significance.
Leucopogon esquamatus	Listed as rare under the Tasmanian *Threatened Species Protection Act 1995.* Occurs extensively in the heathland below the slopes of Mt Munro.
Lomatia tinctoria	Endemic in Tasmania, close to northern extent of distribution.
Pseudanthus ovalifolius	Uncommon in Tasmania, confined to gravelly, siliceous soils in eastern parts of the State and the three largest islands in the Furneaux Group.
Spyridium gunnii	Isolated population, in the Furneaux Group found only on higher peaks.

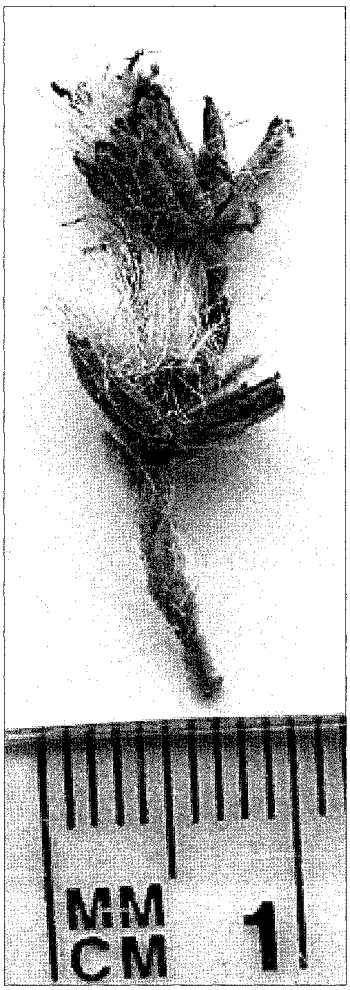

PLATE 1
The seed of Bedfordia arborescens.

are boundaries between patches of varying dominance reflecting different fire ages. The patches of *B. arborescens*-dominated forest, if remaining unburnt, will be reinvaded by *A. moschatum, D. antarctica* and other rainforest species. *B. arborescens* may represent a successional stage within the forest.

Tree diameter is known to be a poor proxy for age because tree diameter increments are known to respond strongly to site conditions. If, however, diameters are aggregated into size classes, then some general inferences can be drawn. First, no small trees with diameters less than 5.8 cm were found, indicating an absence of recruitment below the ages this size may represent. Most trees that were measured fall in diameter class ranges between 5 and 25 cm. Fewer specimens then occurred up to 39 cm. A large gap exists up to the largest individual measured at 55 cm dbh (fig. 6). This specimen may represent a small number of trees on the mountain that have survived from a much earlier cohort than is represented by other measured trees. This would indicate a recruitment gap with missing cohorts that could mean that disturbance across the mountain retarded recruitment of *B. arborescens* for some period of time. It is possible that the largest individual represents a surviving cohort from pre-settlement disturbance and the size gap below this indicates the beginning of new stands resulting from a period of high fire frequency.

PLATE 2
Bedfordia arborescens *killed by fire on Mt Munro.*

Autecology

B. arborescens occurs as a robust, umbrageous tree 6–8 m high in the study area. Observation of individuals showed that they were always in a healthy condition with no senescence. Where physical damage had occurred to individual trees, such as breakage from wind throw, there was an epicormic response on broken limbs, provided there was still bark continuity. Shoots thus produced have a strong apical dominance, taking advantage of a break in the canopy cover. These fast-growing shoots contrast with the spreading foliage of dominant *Bedfordia* trees in the forest that have probably regenerated in a single cohort and subsequently self-thinned. In the apparently older forests, some physical damage of individuals was observed. It is not clear whether this had resulted from direct or indirect wind throw damage, or whether the trees are nearing the end of their life span.

The species is killed by fire. This is apparent through examining the pattern of vegetation boundaries. Instances were observed where dead *B. arborescens* occurred behind a fire boundary (pl. 2). The adaptive significance of the thick, spongy bark in mature specimens is uncertain in this context. We did note, however, during heavy mist, that water was being captured by the crown and directed down the bark fissures. This might be an adaptive mechanism for a cloud-stripping species. The foliage is mesophilous and rapidly wilts if conditions become dry. The species may therefore be intolerant of prolonged dry conditions. Epicormic recovery is likely to occur, following fire as it is a common response in *Bedfordia salicina.*

Reservation and Conservation Status of *B. arborescens*

B. arborescens is not known to occur within any reserve in Tasmania and its total extent is on Aboriginal land. The BIOCLIM predictions suggested that suitable climatic habitat existed in northeastern Tasmania in the Blue Tier and mounts Victoria and Albert region. Interestingly, no suitable climatic habitat was predicted anywhere else in the Furneaux Islands beyond Mt Munro. This is despite the existence on Flinders Island of mountains with cloud forest and many other shared species (Harris *et al.* unpubl. data). One prediction gave a high probability of *B. arborescens* occurring to the east of our own field records. We believe this is possible, as the area is

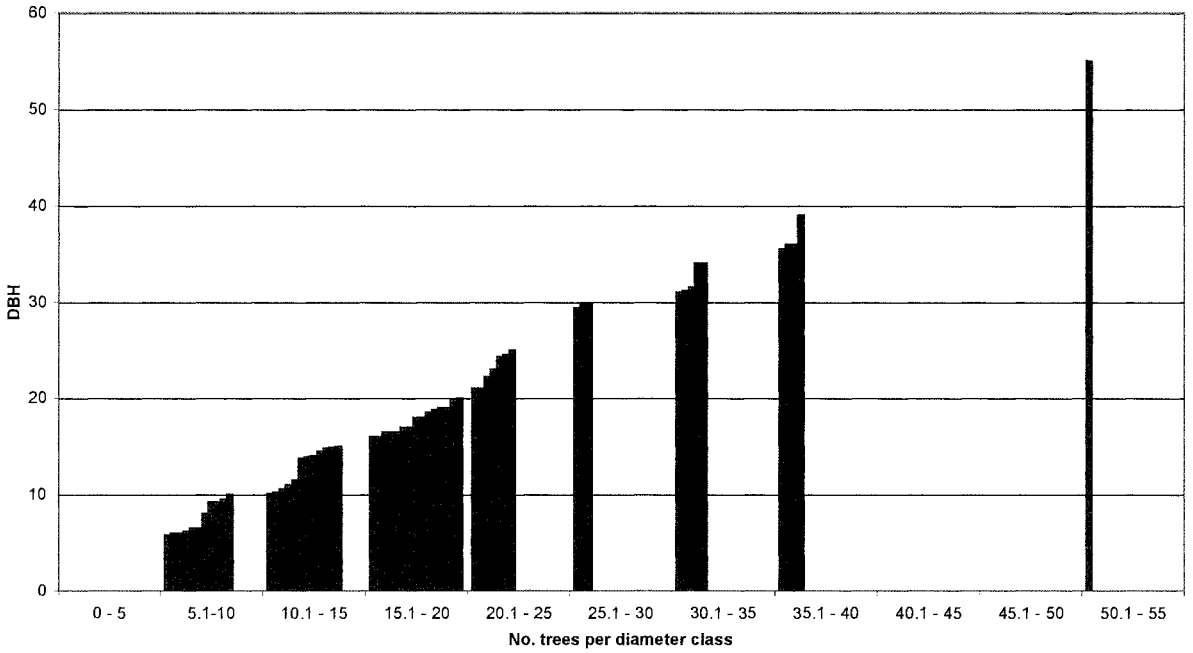

FIG. 6 — Diameter classes of Bedfordia arborescens *on Mt Munro.*

still on the Mt Munro massif and the compatible vegetation occurs in the predicted region. Confirmation must await further visits. Targeted surveys in likely habitat on Flinders Island to the north failed to locate the species.

Presently, *B. arborescens* is listed as rare on schedule 5 of the Tasmanian *Threatened Species Protection Act 1995* and was designated an R1 species (Flora Advisory Committee 1994). No *Bedfordia* is listed as threatened in other States.

Given current data, *B. arborescens* qualifies for listing as vulnerable at the State level using the guidelines for the listing of species on the Tasmanian *Threatened Species Protection Act 1995* because:

- there are fewer than 10,000 mature individuals;
- there is no population with over 1,000 individuals;
- there is a continuing decline. A continuing decline is inferred due to a high fire frequency on the island.

GENERAL DISCUSSION AND MANANGEMENT RECOMMENDATIONS

This study represents the first examination of the habitat, ecology and status of *B. arborescens* in Tasmania and must be viewed as a reconnaissance-level examination. Our discussion is limited by the lack of studies on the genus elsewhere.

Our observations are consistent with the general ecology of members of the Asteraceae, many of which regenerate prolifically, especially after disturbance. In this case, however, these attributes are applied in the context of a long-lived tree in an unusual environment, which is significant. Tree-form Asteraceae are uncommon worldwide. Notable examples of gigantism in herbaceous Asteraceae are reported in situations that are either islands or habitat islands on mountains in a continental situation. Examples are described in the literature from Africa, and on a number of oceanic islands. These include *Senecio huntii* from the Chatham Islands and *S. stewartiae* from the islands in the Foveaux Strait in New Zealand (Allen 1982).

Bedfordia is not common in the Furneaux Islands. A search of collections in the Tasmanian Herbarium reveals no records of *B. salicina* from the Furneaux Islands. *B. linearis* has been recorded from Flinders Island at Broughams Sugarloaf, Summer Camp Gully and near Emita. The taxonomic boundary between *B. salicina* and *B. linearis* has been regarded as indistinct by some fieldworkers (Kirkpatrick & Backhouse 2004). We believe *B. arborescens* on Cape Barren Island to be very distinctive from forms of *B. salicina* or *B. linearis*. It is likely that the genetic make up of this population varies significantly from mainland populations. This would result from separation of populations over a span of at least 10,000 years (being the time since the post-glacial formation of Bass Strait).

The long-term survival of *B. arborescens* here must be considered in the context of the vegetation pattern on the mountain and the natural and human processes shaping it. Over successive glacial cycles Mt Munro has, alternately, been a high point on an extensive plain (Jackson 1990) between the mountains of Wilsons Promontory and northeast Tasmania, and an island mountain surrounded by seas. Apart from Cape Barren Island and the other major islands in the Furneaux Group, there is nowhere else in Australia where we can confidently say that humans were absent for a period of approximately 4500 years during the Holocene. Since human occupation and visits to Cape Barren Island recommenced about 200 years ago, fire frequency is likely to have increased. The interactions of fire and biophysical variables have created an interesting vegetation pattern.

The vegetation map indicates a zone of cloud forest, generally above 280–300 m altitude, below which heathland, scrub and eucalypt forests occur. This transition may have been differently expressed in the vegetation 200 years ago. Repeated firing has reduced the general stature of vegetation and eroded the distribution of tall forests and fire-prone forests to the extent that these now occur only in more fire-protected sites on the mountain. Open heathland and scrub may have replaced forests and woodlands of *Eucalyptus nitida*,

PLATE 3
Eucalyptus *(probably* globulus*) stag on the edge of* Bedfordia arborescens *cloud forest*

PLATE 4
Eucalyptus *(probably* globulus*) stags scattered over grassland adjacent to relict* Bedfordia arborescens *stand.*

as well as *Callitris rhomboidea* with dense understorey of *X. australis*. Remnant bluegum forest with open understorey and with bracken as a prominent ground species may have replaced tall *E. globulus* forests with dense understorey. Vegetative reproducers and anemophilous species appear to exceed the biomass of the few obligate seeders. Above the base of the cloud layer, forest once dominated by *A. moschatum* has been replaced by forest dominated by *P. apetala, B. arborescens, Acacia verticillata* and *N. ligustrina*. These forests in turn have been replaced by scrub dominated by *Leptospermum* sp., *A. verticillata, Zieria arborescens* and *Lepidosperma elatius.*

The interception of water from the atmosphere results in cloud forest and has been widely documented in tropical and subtropical systems (Hutley *et al.* 1997, Bruijnzeel & Veneklaas 1998).

Emergent trees with large leaf surface areas may account for increased annual precipitation totals of the order of 200% through the action of "cloud drip" (Page 1979 cited in Rigg *et al.* 2002). Dense populations of epiphytic cryptogams and ferns often typify such forests. The *B. arborescens* on Mt Munro appear to have abundant epiphytic cryptogams and ferns.

The disclimax grasslands on the mountain are comparable with the subalpine grasslands in northeast Tasmania (Ellis 1985, Ellis & Grayley 1987) where the destruction of rainforest by fire has resulted in the creation of grasslands. The remains of *Eucalyptus* (probably *globulus*) stags and downers on Mt Munro indicate the previous vegetation type (pls 3, 4). On Flinders Island, *Poa* grasslands resulting from repeated firing of eucalypt forest have developed on Walker's Lookout in the Darling Range.

The grassy ridgetops of the Mt Munro massif may be analogous with the montane grasslands within the matrix of rainforest that occurs in parts of New Guinea. Paijmans (1976) states that fires on Mt Wilhelm are more irregular than in lowland grassland because of the greater dampness, the shorter and less reliable dry season and the more abundant wet and less flammable patches. The effect of fires in this environment produces a mosaic of successional and subclimax stages. He also points out that certain grasses prefer crests in New Guinea where fire is more frequent.

Anthropogenic firing is a likely cause of grassy balds or grasslands in grassland/forest mosaics. Fensham & Fairfax (1996) describe such a mosaic in the Bunya Mountains in Queensland where no strong environmental correlation is apparent with the occurrence of grassland, and disturbance such as firing is the most likely explanation.

Fire management on Cape Barren Island, until as recently as about five years ago, involved frequent burning carried out by the island inhabitants. A Parks and Wildlife Service ranger stated that "The island was burnt in large patches traditionally every 3 to 4 years" (C. Arthur, letter to N. Walsh 2004). Prior to human settlement in the Bass Strait islands, it seems likely, by inference from the historical records available to us, that there was extensive forest and scrub vegetation on Cape Barren Island. There are insufficient historical observations for confidently reconstructing in any detail the pre-settlement vegetation. However, the present patterns are consistent with a high fire frequency over at least the past hundred years.

On Mt Munro the extent of cloud forest dominated by *A. moschatum* and *B. arborescens* and other trees, appears to have been eroded by fire in historical times. The grassland has been maintained by frequent low-intensity fires that have also allowed preservation of remnant cloud forest through reinforcement of sharp differences in soil moisture and nature of fuels. The prevalence of large downers of what are likely to be *E. globulus*, suggests that prior to the pyrogenesis of the grasslands, the previous fire would have dated from the origin of the eucalypts now lying on the grassland floor. The eucalypts probably represented scattered emergents over a rainforest understorey, probably acting as a "nursery tree" harvesting moisture from clouds and increasing the moisture availability to the immediate understorey, in the same way as indicated for *Araucaria laubenfelsii* on Mt Do in New Caledonia (Rigg *et al.* 2002). An alternative hypothesis is that the eucalypt litter allowed the fire to penetrate where they were present and that the stands without eucalypts were relatively fire resistant.

The Broad-leaf scrub (SBR) community has the potential to reach a rainforest climax provided there are suitable seed sources in the vicinity.

There are possibly strong affinities with some of the rainforest communities described by Peel (1999) for Victoria. These include warm temperate rainforest and dry rainforest communities such as the "East Gippsland overlap warm temperate rainforest" community and the "coastal range overlap warm temperate rainforest" community. The floristic similarities of the Mt Munro stands and some of

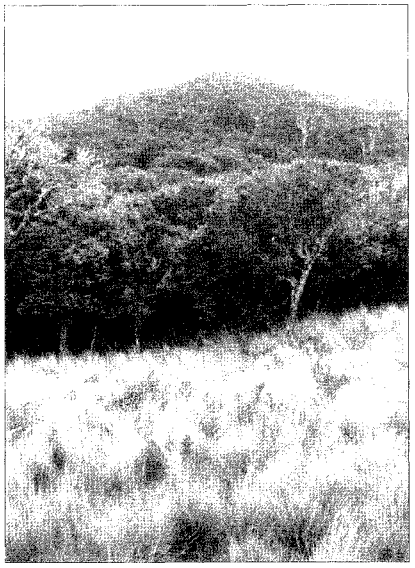

PLATE 5
The sharp forest/grassland boundary on the upper slopes of Mt Munro.

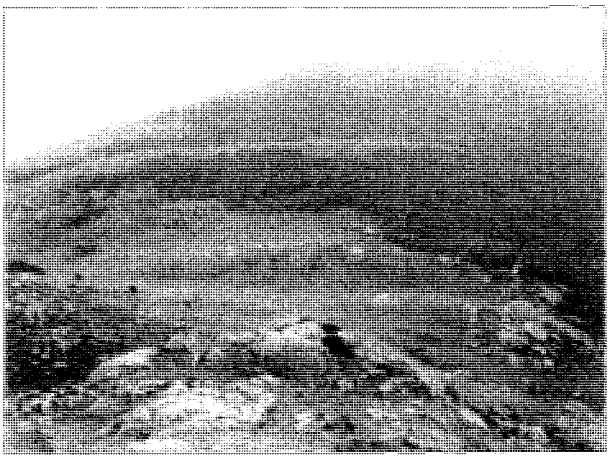

PLATE 6
Fire induced and maintained vegetation patterning above the lower limit of the cloud cap on Mt Munro.

the quadrats in the Victorian study are very strong. *B. arborescens* on Cape Barren Island occurs within (or close to) the Tasmanian range of several rainforest outliers that comprise the companions to *B. arborescens* in Victoria. These include *Elaeocarpus reticulatus*, *Pandorea pandorana* (on nearby Flinders Island), *Polyscias* spp. and *Pomaderris aspera*. The environmentally-limiting factors for *B. arborescens* will not be identified until experimental work is carried out on the species. This will be difficult, as there has been almost no success reported for seed germination from Mt Munro collections (W. Fletcher, Plants of Tasmania Nursery, pers. comm.) although in Victoria, Dr David Ashton (University of Melbourne, pers. comm.) germinated seedlings from handfuls of sieved soil incubated in a glasshouse for some months.

The reservation and conservation status of the *B. arborescens* deserves attention. The former Crown land on Cape Barren Island was vested in the Aboriginal community in March 2005. The International Union for the Conservation of Nature has specified a classification of reserves. Category V Protected Landscape states as one of its primary management objectives, "to provide for use by either Aboriginal or non-Aboriginal communities for those traditional activities that are important in determining the distinct ecological characteristics of the area". Such a category would be compatible with Mt Munro on Cape Barren Island. Alternatively a discrete area of highly significant nature conservation values could be formally designated as a Strict Nature Reserve (Category 1a under IUCN). The conservation status of *B. arborescens* has been reassessed as vulnerable, and this paper will be useful to inform the process of uplisting the species.

Peripheral populations of species are known to be valuable for conservation because there is likely to have been genetic divergence from central populations. Advantages of conserving such peripheral populations have been described by Lessica & Allendorf (1995). A study of the genetic make-up across the total range of *B. arborescens* would be of fundamental interest, as it would establish whether the Cape Barren Island population was a genotype distinct from the mainland. If so, its conservation importance may be considered to be greater. The genetic variation between forest pockets on Mt Munro would be of interest also. We hypothesise that there would be no significant differences across these sub-populations, but also that there may well be differences between Cape Barren Island and mainland Australian populations. The 10,000 years since the beginning of the Holocene is enough time to produce genetic drift. Genetic studies would therefore be valuable for understanding the species. The importance of such work as a background for species conservation planning is demonstrated by Shapcott (1994), who investigated a rainforest species that may have some parallels with *B. arborescens*. There is scope for research on a variety of topics that would broaden our understanding of this species and its ecology, as well as assist its management in the long term.

Our work has indicated that this species is strictly an 'r' strategist, but is likely to rely on a narrow temporal opportunity for establishment following fire. No evidence of gap phase or continuous regeneration is apparent; however, it appears that a major disturbance event such as fire will encourage establishment. The grassland areas between stands of rainforest with *B. arborescens* are likely to be hostile to seedling regeneration because of water stress, grass competition and high insolation, particularly in the absence of any nursery crop. Regeneration of *Bedfordia*, on the other hand, may be optimal where forest patches are burned in the occasional intense fire. That is, the relict rainforest patches that currently occupy gullies or shaded slopes and containing *B. arborescens* may need occasional fire for regeneration of *B. arborescens*. Propagules from adjacent patches would be blown into these areas, and may have a higher likelihood of establishment due to the naturally damper substrate and the probability of a rapidly regenerating nursery crop, for example of *Z. arborescens*. Under the current regime of frequent fires, the grassland/forest boundary (pl. 5) is being reinforced and fire incursion into the forest is most likely rare because of the limited fire carrying capacity of the adjacent grassland.

Studies elsewhere (e.g., Duncan & Duncan 2000) indicate that forest succession into grasslands can be very slow, partly because of competition for nutrients and the especially vigorous nature of grasses. Fensham & Kirkpatrick (1992)

have demonstrated in the Tasmanian Highlands that the development of a dense grass sward is inhibitive to the establishment of trees.

Further research on *B. arborescens* is required before it is possible to be confident about species and habitat management directions.

The existing vegetation pattern (pl. 6) is likely to reflect a higher fire frequency over the past 200 years than previously. There is currently no fire management plan for Cape Barren Island. Discussion between natural resource managers and local Aboriginal land managers would assist the development of an ecologically sustainable fire frequency.

Evidence of vehicle tracks was observed on Big Hill and adjacent flanking ridges. Easy access by vehicle can facilitate damaging activities to occur. The tracks appeared to be relatively recent in March 2004; however, with the increase in capability and versatility of off-road vehicles, motorised access could penetrate many more parts of the mountain, to the detriment of natural values. Such activities could be controlled through specifications in a formal management plan and its subsequent enforcement.

Managers of threatened species need to consider the long-term impacts of global and regional climate change. Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases is listed as a key threatening process under the provisions of section 183 of the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*. The trends indicate that global warming is occurring, particularly an increase in minimum temperatures (CSIRO 2004). Projections for seasonal and annual warming ranges indicate increases up to around 4° C by 2070. A recent study predicted a modest increase in temperature of less than 1° C by 2040, and northeastern Tasmania becoming drier by 70–140 mm (McIntosh *et al.* 2005). A general decrease in summer rainfall and an increase in winter rainfall in Tasmania is predicted. It is not possible to be very accurate about the changes for this locality, although it is likely that there will continue to be climatic conditions conducive to maintenance of the existing vegetation pattern in the next 40 years at least. While studies have been made on possible climatic-induced changes to tropical cloud forests (Loope & Giambelluca 1998, Foster 2001) the future of extra-tropical cloud forests is uncertain. Long-term monitoring of vegetation and selected climatic variables on Mt Munro would be of great interest for understanding the long-term outlook here for *B. arborescens*.

Specific changes to the microclimate of Mt Munro may already have been occurring over the past 200 years as a result of a very high fire frequency on the surrounding plains that has converted forest and woodland to heath and sedgeland. Evidence for tropical montane cloud forests (Lawton *et al.* 2001) indicates ascension of the cloud base following clearing of surrounding lowland forest. We are uncertain about the applicability of this tropical situation to the Mt Munro environment, where montane forest was formerly surrounded by dry forest rather than rainforest.

Ex-situ conservation strategies, particularly given that the seed may be classed as recalcitrant, may be limited. Long-term storage of the seed in a seed bank may therefore not be an option; however, viability and longevity of seed should be assessed. Before *ex-situ* measures are considered, a fire management plan for the mountain and surrounding areas suggests itself as a priority. Continued liaison between the community Cape Barren Island Aboriginal Association and vegetation ecologists would be productive in considering fire management of the unique vegetation of Mt Munro.

The remnants of the cloud forest represent habitats that are unusual, or at least rarely recorded, in the scientific literature for temperate and Mediterranean climates. The presence of cloud stripping forest is the likely reason for the persistence on Mt Munro of the outlying population of *B. arborescens*, remote from its nearest neighbours on mainland Australia.

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We dedicate this paper to the memory of Dr Irynej Skira (1950–2005) who made a substantial contribution to knowledge of the wildlife and history of the Furneaux Islands.

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APPENDIX 1

Short descriptions of vegetation communities in the study area. Nomenclature follows Harris & Kitchener (2005).

Broad-leaf scrub (SBR)

This short rainforest is generally up to 8–10 m high with a dense canopy and open understorey in most cases. It occurs in gullies, depressions and shaded slopes but has abrupt boundaries with some other communities. *Eucalyptus globulus* may have been a more common emergent in these forests. Fire frequency is very low.

Species observed in this community include *B. arborescens, A. moschatum, Olearia argophylla, P. apetala, N. ligustrina, Acacia melanoxylon, Leptecophylla juniperina, P. drupacea, P. bicolor, C. quadrifida, Z. arborescens, Senecio* sp., *Cyathea australis, Asplenium bulbiferum, Pellaea falcata, Polystichum proliferum, Histiopteris incisa, Hypolepis* sp., *Hymenophyllum australe, Hymenophyllum cupressoides, Hymenophyllum flabellatum, Parsonsia straminea, Ctenopteris heterophylla, Rumohra adiantiformis, Polyphlebium venosum, Clematis aristata, D. antarctica* and *Microsorum pustulatum.*

Broad-leaf scrub (SBR) post-fire regeneration

This community is extensive around the mountain and generally occurs above the lower limit of the cloud forest effect. It comprises dense *Z. arborescens* associated with some other species. There are often large *Eucalyptus* downers.

Species observed in this community include *Z. arborescens, L. elatius, Gahnia grandis, Goodenia ovata, A. verticillata, Olearia lirata, Pteridium esculentum, E. globulus* (occasional emergent), *E.nitida* (occasional emergent), *P. drupacea* and *M. pustulatum.*

Lowland Poa labillardierei grassland (GPL)

This grassland occurs on the higher ridges and slopes below Mt Munro and often has sharp boundaries with other communities. It is an apparent fire disclimax community because there are numerous logs on the ground from burnt *E. globulus* emergents over rainforest. The grassland is dominated by *P. labillardierei* with a number of herbs, shrubs and other grasses.

Species observed in the community include *P. labillardierei, Kunzea ambigua, Allocasuarina verticillata, Aira* sp., *Austrodanthonia* sp., *Trifolium* sp., *Asteraceae* sp., *Oxalis perennans, Hydrocotyle* sp. *Ehrharta* sp., *Asperula* sp., *P. esculentum, L. juniperina, Epacris impressa, Juncus* sp., *Lepidosperma* sp., *Gahnia* sp., *Lindsaea linearis, Austrodanthonia* sp. *Luzula* sp., *Viola* sp., *Acetosella vulgaris, Dichondra repens.* and *Wahlenbergia* sp.

Eucalyptus globulus dry forest and woodland (DGL)

E. globulus forest and woodland was probably more extensive around Mt Munro but the dominant tree has been killed by fire. It is commonly a tall forest up to 25 m high with prolific shrub layer that includes many of the mesophilous shrubs listed under broad-leaf scrub. Above the lower limit of the cloud cap, *E. globulus* has the potential to persist over rainforest understorey.

Species observed in the community include most of those listed under broad-leaf scrub and broad-leaf scrub (post-fire regeneration).

Eucalyptus nitida Furneaux forest (DNF)

One of the most common eucalypt forest types in the Furneaux Islands, this community ranges from short forest and woodland to tall forest. In the study area, the community occurs as young forest 8–10 m high to older forest up to 20 m high. This forest is more typical of very low nutrient soils and drier sites than *E. globulus* forest. The two eucalypts are occasionally found together. Often there is a dense shrub layer in gullies and higher slopes.

Species observed in the community include, at the wetter end of the spectrum, many of the species found in *E. globulus* forest. In the drier forest at lower altitudes in the study area, the following species were observed: *Leptospermum scoparium, K. ambigua, Lasiopetalum macrophyllum, G. grandis, Xanthorrhoea australis, Acacia mucronata, O. lirata, Correa reflexa* and *L. elatius.*

Heathland on granite (SHG)

This is an extensive heathland type in the study area. Although the heathland is capable of succeeding to scrub and forest, frequent fires have maintained the heathland formation. Mallee form *E. nitida* is commonly scattered throughout and the understorey is characterised by a diverse shrubby flora or a graminoid-dominated flora where *P. cinnamomi* has affected the community in which case it is mapped as Lowland sedgy heathland.

Species observed in this community include *Acacia genistifolia, A. mucronata, P. apetala, Callistemon viridiflorus, C. quadrifida, Leptomeria drupacea, K. ambigua, Lepidosperma concavum, Acacia myrtifolia, Hakea epiglottis, Persoonia juniperina, X. australis, Hakea nodosa, Hakea teretifolia, B. marginata, Leptospermum glaucescens, Allocasuarina monilifera, L.scoparium* and *Cryptostylis leptochila.*

Lowland sedgy heathland (SHL)

This heathland community is an artefact of extensive *P. cinnamomi* infection, which has eliminated many plants from susceptible families. The result is a graminoid-dominated heathland on slopes with fairly uniform drainage. The species composition is a depauperate version of the coastal heathland community. The dominant graminoids in rhis community type include *Lepidosperma filiforme, L. concavum, Baumea* spp., *Leptocarpus tenax* and *Hypolaena fastigiata.*

Coastal heathland (SCH)

This community occurs in the lowest altitude sites in the study area on coastal sand and other siliceous sediments where *P. cinnamomi* has had a minimal effect and shrub diversity is high.

Species observed in this community include *A. genistifolia, L. glaucescens, Xanthosia pilosa, Leucopogon collinus, L. concavum, H. fastigiata, A. myrtifolia, X. australis, Dillwynia* sp., *Acacia suaveolens, B. marginata, E. impressa, Patersonia fragilis, Selaginella uliginosa, Dampiera stricta, H. teretifolia, P. juniperina, Aotus ericoides, Lomatia tinctoria, Pseudanthus ovalifolius, Platylobium triangulare* and *Leucopogon esquamatus.*

Dry scrub (SDU)

This community is common throughout the Furneaux Group especially on Cape Barren Island, where frequent fires have given expression to an abundance of early successional stages. Species such as *L. scoparium, A. mucronata, A. verticillata* and *B. marginata* have the potential to become trees. Due to the density of the scrub there is usually low species diversity but some species may be entirely represented by soil stored seed that would germinate after fire.

Species observed in this community include the longer-lived elements from coastal and lowland sedgy heathland.

Lichen lithosere (ORO)

This community occurs on extensive areas where the granite bedrock is at the surface. Shrubs and vascular plants may occur in crevices but the dominant flora are cryptogams.