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Tasmania's giant eucalypts: discovery, documentation, macroecology and conservation status of the world's largest angiosperms

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ABSTRACT

Context. Tasmania is the epicentre of the tallest and most massive angiosperms on Earth. **Aims.** To survey Tasmania's tallest and most massive (large trunk volume) trees. **Methods.** LiDAR and satellite imagery identified areas with very tall trees. Field surveys recorded the geolocation, height, diameter and condition of exceptionally large individuals, and effects of recent fires. **Key results.** Giant trees occur in a band between dry forests and temperate rainforests, with the largest trees in areas with 1000–1500 mm rainfall and 8–12°C mean annual temperature. We documented 18 trees taller than 90 m, and 32 trees with trunk volume of >250 m^3. Trunk volume was better correlated with diameter at 10-m height than at breast height, owing to irregularities near the base of large trees. The tallest tree was measured to be 99.6 m tall (now 96 m tall), and the most massive tree had a trunk volume of 460 m^3. Most of the largest and tallest trees in Tasmania were *Eucalyptus regnans*, but occasional individuals of *Eucalyptus globulus, E. obliqua* and *E. tasmaniensis* were also over 85 m tall or had a trunk volume of >280 m^3. Post-fire surveys highlighted vulnerability of giant *Eucalyptus* trees to fire, with 60% of the largest known trees killed by fire since 2004. **Conclusions.** The giant trees of Tasmania are of global significance, but vulnerable to a warming, drying climate and associated increase in fire activity. **Implications.** We outline steps for the conservation of giant trees, a task made urgent by climate change.

Keywords: *Eucalyptus globulus*, *Eucalyptus obliqua*, *Eucalyptus regnans*, giant trees, old growth forest, remarkable trees, tall trees, tree height, tree size, veteran trees.

Introduction

Exceptionally tall or massive trees have long been a source of great human interest and fascination (Griffiths 1992; Carder 1995; Flint 2002). Part of this captivation is due to the sheer physical presence of the trees and the accompanying mystique regarding their age. Equally, the environmental, climatic, and genetic circumstances that enable them to grow to such a size are also of great interest scientifically. In addition, the wood products from these large trees and the forests they inhabit are of immense commercial significance (Dargavel 1995; Department of Agriculture, Fisheries and Forestry 2022). Exceptionally large size is a result of very fast growth rate, extreme longevity, or more commonly, both. Globally, large old trees across a wide range of forest types have been in decline in modern times, largely as a result of logging, with serious implications for habitat, biodiversity and ecological services that the trees provide (Lindenmayer *et al.* 2012; Jones *et al.* 2018). The definition of what height defines a very tall tree or what trunk diameter or trunk volume constitutes a very large species varies and is obviously subjective. Carder (1995) proposed that 'a species enters the big tree category if it has produced a specimen or specimens either 200 feet (61 m) or more in height, or a bole 12 or more feet in diameter at breast height' (pp. xiv–xv) (girth of 37.7 feet or 11.5 m). However, applying Carder's definition worldwide would include many hundreds of tree species. Tng *et al.* (2012) noted that there are only 50 tree species globally that produce specimens over 70 m in height and these represent less than 0.005% of an estimated total of 100,000 tree species in the world. However, to limit

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the definition of a giant tree even further to only the top 20 tallest or largest tree species, we here further define 'giant' as a tree that has produced a specimen or specimens that exceed 200 m^3 in trunk volume and/or 84 m in height. Trunk volume is calculated from measurements of height and multiple diameter measurements at regular intervals along the bole of the tree (Van Pelt 2001). However, across species, volume does not necessarily scale closely to mass, because wood density varies. The density of hardwood is typically greater than that of conifers; for example, average density of tall Tasmanian eucalypt species ranges from 0.59 kg m^{-3} (*E. tasmaniensis*) to 0.71 kg m^{-3} (*E. globulus*), compared with 0.38 kg m^{-3} (*Sequoia sempervirens*) to 0.45 kg m^{-3} (*Pseudotsuga menziesii*) for North American tall conifer species (ICRAF 2023). The high wood density of eucalypts means that their trunk wood biomass is greater than that of a conifer of equivalent volume. Recent analyses showed that globally, the largest trees, and fastest growth rates, are found in forests growing in cool wet climates (Tng *et al.* 2012; Scheffer *et al.* 2018). These conditions are consistent with those under which the largest, fastest-growing eucalypt species occur (Bowman *et al.* 2014).

It is well known that the largest and tallest trees on earth are conifers growing in a narrow band of the Pacific Northwest of North America (Sillett *et al.* 2021; Tables 1, 2). However, the tallest and largest flowering plants in the world are some eucalypt species from Australia, where there are no large conifers (Williams *et al.* 2023). Indeed, the only exceptionally large conifers in the southern hemisphere are two species from New Zealand (https://www.notabletrees.org.nz/champion-trees). Another intriguing aspect of giant eucalypts is their deep evolutionary history and adaptations to fire (Crisp *et al.* 2011). Their ecology is inextricably linked with fire disturbance (Tng *et al.* 2012). For example, the unique epicormic anatomy in eucalypts has been estimated to have evolved at least 60 million years ago (Crisp *et al.* 2011). Additionally, it has been long established that fire is the main regenerative agent in tall wet eucalypt forests (Gilbert 1959; Ashton 1976, 1981, 2000; Attiwill 2002). As explained below, this paper provides an extensive, contemporary evaluation of Tasmanian giant trees on the basis of field surveys. Our data and analyses enable us to understand their biogeography, ecological dynamics, history of land use, and conservation status and situate these threatened plant communities in a global context.

Aims and objectives

There has been only one published paper on Tasmania's tallest trees (Hickey *et al.* 2000), and none on Tasmania's most massive trees. Comprehensive surveys of giant trees are lacking, particularly those investigating the local environmental controls and landscape settings. Such studies have been stymied by the lack of systematic remote-sensing and field surveys, high-quality climate data and geospatial data, which have become available only this century. Recently, giant trees have been discovered and documented by

Table 1. World's tallest known tree species ranked by height.

Tree species	Family (gymnosperm/angiosperm)	Location	Height (m)	Reference
Sequoia sempervirens	Cupressaceae (gymnosperm)	California	115.57	Sillett *et al.* (2021)
Cupressus gigantea	Cupressaceae (gymnosperm)	Tibet	102.3	Fangyu (2023)
Picea sitchensis	Pinaceae (gymnosperm)	California	100.2	Sillett *et al.* (2021)
Pseudostuga menziesii	Pinaceae (gymnosperm)	Oregon	99.5	Sillett *et al.* (2021)
Shorea fagueteana	Dipterocarpaceae (angiosperm)	Sabah, Borneo	98.53	Shenkin *et al.* 2019
Eucalyptus regnans	Myrtaceae (angiosperm)	Tasmania	99.82	This paper
Sequoidendron giganteum	Cupressaceae (gymnosperm)	California	96.3	Sillett *et al.* (2021)
Eucalyptus globulus	Myrtaceae (angiosperm)	Tasmania	90.7	This paper
Angelim vermelho (*Dinizia excelsa*)	Fabaceae (angiosperm)	Brazil	88.5	Phys.org (2022)
Eucalyptus obliqua	Myrtaceae (angiosperm)	Tasmania	88.5	This paper
Eucalyptus delegatensis	Myrtaceae (angiosperm)	Tasmania	86	This paper
Koompassia excelsa	Fabaceae (angiosperm)	Sabah, Borneo	85.76	B. Mifsud (pers. comm.) 2007
Abies procera	Pinaceae (gymnosperm)	Washington	85.3	R. Van Pelt (pers. comm.)
Eucalyptus cypellocarpa	Myrtaceae (angiosperm)	Victoria	85	Mifsud (2024)
Shorea argentifolia	Dipterocarpaceae (angiosperm)	Sabah, Borneo	84.84	B. Mifsud (pers. comm.) 2007
Shorea superba	Dipterocarpaceae (angiosperm)	Sabah, Borneo	84.4	B. Mifsud (pers. comm.) 2007
Eucalyptus nitens	Myrtaceae (angiosperm)	Victoria	84.3	Mifsud (2002)
Eucalyptus saligna	Myrtaceae (angiosperm)	South Africa (planted)	83.7	Magoebaskloof Tourism Association (2022)

Taxonomic identity, geographic location, and source are listed.

Table 2. Global summary of tree species known to have specimens of over 200 m^3 in wood volume.

Species	Family (gymnosperm/angiosperm)	Location	Trunk volume of largest extant tree (m^3)	Source
Sequoiadendron giganteum	Cupressaceae (gymnosperm)	California	1395	Sillett *et al.* (2021)
Sequoia sempervirens	Cupressaceae (gymnosperm)	California	1083	Sillett *et al.* (2021)
Taxodium mucronatum	Cupressaceae (gymnosperm)	Mexico	705	https://www.conifers.org/cu/Taxodium_mucronatum.php
Eucalyptus regnans	Myrtaceae (angiosperm)	Tasmania (and Victoria)	463	This paper
Thuja plicata	Cupressaceae (gymnosperm)	Pacific Northwest America	449	Van Pelt (2001)
Adansonia digitata	Malvaceae (angiosperm)	Southern Africa	414	Guinness World Records (2023*a*)
Adansonia grandidieri	Malvaceae (angiosperm)	Madagascar	410	Guinness World Records (2023*a*)
Pseudotsuga menziesii	Pinaceae (gymnosperm)	Pacific Northwest America	350	Van Pelt (2001)
Picea sitchensis	Pinaceae (gymnosperm)	Pacific Northwest America	332	Van Pelt (2001)
Agathis australis	Araucariaceae (gymnosperm)	New Zealand	315	https://www.conifers.org/ar/Agathis_australis.php
Eucalyptus globulus	Myrtaceae (angiosperm)	Tasmania (and Victoria)	305	This paper
Eucalyptus obliqua	Myrtaceae (angiosperm)	Tasmania (and Victoria)	296	This paper
Pinus lambertiana	Pinaceae (gymnosperm)	California and Oregon	255	Van Pelt (2001)
Chamaecyparis formosensis	Cupressaceae (gymnosperm)	Taiwan	250	R. Van Pelt (pers. comm.)
Calocedrus decurrens	Cupressaceae (gymnosperm)	Pacific Northwest America	230	Van Pelt (2001)
Eucalyptus nitens	Myrtaceae (angiosperm)	Victoria (and New South Wales)	229	Mifsud and Harris (2016)
Eucalyptus nobilis	Myrtaceae (angiosperm)	New South Wales	220	This paper
Eucalyptus denticulata	Myrtaceae (angiosperm)	Victoria	205	Mifsud and Harris (2016)
Cupressus gigantea	Cupressaceae (gymnosperm)	Tibet	205	https://www.conifers.org/cu/Cupressus_gigantea.php
Eucalyptus tasmaniensis	Myrtaceae (angiosperm)	Tasmania	205	This paper
Podocarpus totara	Podocarpaceae (gymnosperm)	New Zealand	204	https://www.conifers.org/po/Podocarpus_totara.php
Eucalyptus diversicolor	Myrtaceae (angiosperm)	Western Australia	203	Du Guesclin (2023)
Eucalyptus jacksonii	Myrtaceae (angiosperm)	Western Australia	201	Du Guesclin (2023)

Taxonomic identity, geographic location, and source are listed.

combining analysis of aerial survey LiDAR data with field exploration, including specialised tree-climbing techniques that enable accurate height and volume measurements (Sillett *et al.* 2015). The compilation of these decades of surveys in Victoria and Tasmania presents an important opportunity to undertake the first comprehensive analysis of the Tasmanian giant eucalypts, thereby positioning them into a global context. Specifically, we

i. undertook a comparative review of historical documentation of giant trees in the late 19th and 20th centuries;
ii. undertook an extensive field survey of Tasmanian giant trees measuring height, and diameter, and trunk volume and assessed individual tree health;
iii. documented associated understorey species and whether the stand was single- or multi-aged.
iv. analysed which environmental conditions are most conducive to producing giant trees, and whether these differed for very tall compared with massive trees;
v. eescribed the environmental envelope for giant trees in Tasmania and Victoria (Australian mainland);
vi. undertook repeated surveys to provide data on the mortality of trees following major wildfires;
vii. contextualise our findings in relation to giant trees elsewhere in Australia and globally; and
viii. consider appropriate management of significant stands of giant trees, including strategies to promote survival of giant eucalypts in a warmer world with more frequent fire.

Methods

Historical review

We reviewed historical written and photographic records of giant-tree measurement in Tasmania and Victoria to contextualise our contemporary measurements. Where possible, we found the primary source material in Tasmanian and Victorian state and university libraries.

Ecological survey

Prospective areas where giant trees may occur were identified by applying a range of methods and technologies including forestry-type maps, LiDAR (Supplementary Fig. S1), satellite imagery, and field reconnaissance (Supplementary Appendix S1 in Supplementary Material). In areas where giant and/or tall trees were found, the location of each giant tree was recorded using a Garmin eTrex 22 × GPS and assigned a field code and a name. During the field survey, we assessed understorey vegetation type around each tree and visually assessed the size-class distribution of the eucalypts within a 50-m radius of the tree.

Tree height

Total tree height was measured as the vertical distance between the mid-point of ground and the tallest part of the tree (Van Pelt 2001), irrespective of whether that tallest part was live foliage or a dead twig, branch, or trunk. The mid-point of ground was calculated by measuring the difference between the high point of ground and low point of ground and dividing by two; this is the best way to approximate the point at which the original seedling first emerged from the ground.

We used climber-deployed tape drops and/or laser rangefinder (methods specified for individual trees in Table 3) to determine tree height. Climber-deployed tape drop is generally considered very accurate, especially if the climber can get to within 2–3 m of the highest point of the tree and then use a measuring pole to touch the top leaves. However, it has the following disadvantages: (i) it is very time-consuming (rarely could you measure more than two trees per day with this method); (ii) there are significant physical dangers in climbing large, old eucalypts, especially when you need to get close to the top of dead or decaying crowns; and (iii) rain and wind can make it difficult to both set a climbing line in the tree to access the higher branches and successfully lower the tape to the ground. Therefore, we used climber-deployed tape drop only when initial laser estimates were higher than 89 m.

Trunk volume

Trunk volume is estimated by segmenting the trunk into a series of truncated cones of (mostly) decreasing diameter (Appendix S1). This requires measuring diameter at multiple known heights up the trunk of the tree, calculating the volume of each truncated cone and summing them. To estimate the trunk volume of Tasmania's most massive trees, we initially measured likely contenders by using a relatively fast approach adapted from Van Pelt (2001) and Flint (2002). If this showed a tree to be close to or exceed 300 m^3 in trunk volume, the volume was then estimated in more detail, as per Kramer *et al.* (2018).

Initially, by using a tape, we measured the diameter at the high point of the ground and at 1.4 m above this. We combined these lower trunk diameters with trunk diameters measured at 5-m intervals up the bole, calculated with a hand-held Relaskop (Macroscope 25/45 8 × 30 ocular, RF Interscience) in conjunction with a laser rangefinder (Nikon Forestry Pro I and II). When trunks were noticeably oval or irregular, measurements were made from various angles and averaged.

For those trees found to be likely to be 300 m^3 in trunk volume, more detailed measurements were made, as follows:

i. A base model of the lower trunk (Fig. 1*a*) was created using photogrammetry and/or iPhone LiDAR scanner (iPhone 12 Pro, Software: Agisoft Metashape) (Fig. 1*c*). Cross-sections of the 3D model were extracted at small height intervals, and each area was then back-calculated into a circle, from which 'functional diameters' were obtained. (Fig. 1*b*).
ii. Diameters of the trunk above the irregularly shaped basal section were measured via climber-deployed tape wraps at 3–5-m intervals to the top of the trunk (or where it forks into multiple smaller branches) (Fig. 2).
iii. All diameter figures from both the base modelling and the climber-deployed tape wraps were combined and used to calculate the total wood volume (Appendix S1).

Fire-killed trees

On multiple occasions between 2015 and 2022, we visited the areas burned by wildfires between 2010 and 2019, to assess the condition of previously measured giant trees. We documented those trees found to be fire-killed, and monitored the condition of fire-damaged trees. Using information from this and other sources, we report the largest trees killed by fire between 2000 and 2023.

Data analyses

Using the coordinates of each measured tree, we derived elevation, aspect, and slope (confirmed from field notes) from Listmap (Department of Natural Resources and Environment Tasmania; https://maps.thelist.tas.gov.au/listmap/app/list/map). We classified the stand containing each giant tree as single- or multi-aged on the basis of field data and by analysis of Listmap LiDAR data (Tasmanian Government 2023*a*). The stand was not classed as multi-aged if there was eucalypt regrowth from human-induced changes such as logging and roads nearby. Preliminary inspection of the data showed no clear north–south difference, but showed an apparent difference between east- and west-facing aspects. Therefore we tested *post hoc* whether there was an effect of aspect on the count of (i) large trees and (ii) tall trees. Aspect was classed as 'easterly' (1–179°) or 'westerly' (181–359°), and a binomial test was used to test whether the counts were significantly different, by using the *base* package of the software R (R Core Team 2024). These models were used to detect statistical differences rather than to predict geographic distributions, given biases in the

Table 3. Tallest living Tasmanian trees ranked by height.

Tree ID	Height (m)	Diameter at 1.4 m (m)	Method	Condition of highest part of tree	River catchment	Notes
ED1 'Centurion'	96.5	3.82	Climbing/laser	Living leaves	Huon	First measured at 99.6 m in 2008
AN1	96.0*	2.58	Climbing/laser	Long dead, small sticks	Styx	Climbed January 2005 and measured at 97 m to dead top
AN2	96.0*	3.50	Climbing	Long dead, small sticks	Styx	Climbed 2001 and 2005
NS1	95.9	2.89	Climbing	Long dead, 10 cm branch	Styx	Climbed 2010
AN3	94.3	3.34	Climbing/laser	Long dead, small sticks	Styx	Climbed 2022
KE4	94.2	4.14	Climbing	Living leaves	Kermandie	Climbed March 2022
WC1	93.3	4.77	Climbing	Living leaves	Esperance	Climbed April 2013
NS2	92.9	2.55	Climbing	Small dead sticks	Styx	Climbed April 2004
AN4	92.0	2.96	Climbing	Living leaves	Styx	Climbed 2001
AN5	91.5	3.02	Climbing	Top dying back	Styx	Climbed 2001
WH2	91.5	5.41	Laser	Living leaves	Upper Derwent	Discovered 2021
AN6	91.4	2.80	Climbing	Recently dead top	Styx	Climbed 2004
AN7	91.4	2.93	Climbing	Recently dead top	Styx	
AN8	91.3	2.48	Climbing	Long dead, small sticks	Styx	
MR1	91.3	2.38	Climbing	Living leaves	Florentine	Younger tree – approx. 220 years old
AN9	90.8	2.70	Climbing	Long dead, small sticks	Styx	
DN5	90.7	4.14	Climbing	Long dead, small sticks	Denison	*Eucalyptus globulus*
AN10	90.4	2.55	Climbing	Recently dead top	Styx	
TH1	89.5	1.91	Climbing	Living leaves	Florentine	Younger tree – approx. 220 years old
TH2	89.5	2.23	Laser	Living leaves	Florentine	Younger tree – approx. 220 years old
WP1	88.5	3.82	Laser	Living leaves	Picton	*Eucalyptus obliqua*
TH3	88.5	2.55	Climbing	Living leaves	Florentine	Younger tree – approx. 220 years old
MC1	88.4	2.16	Laser	Living leaves	McCleods	Younger tree
WH4	88.0	4.20	Laser	Living leaves	Wayatinah	Discovered using LiDAR
TH4	88.0	2.38	Laser	Living leaves	Florentine	Younger tree – approx. 220 years old
MR2	88.0	2.55	Laser	Living leaves	Florentine	Younger tree – approx. 220 years old
DN6	88.0	4.45	Laser	Long dead, small stick	Denison	*Eucalyptus globulus*
WR1	88.0	3.82	Laser	Living leaves	Huon	

The diameter, condition and location in major river catchments are also listed for all known trees ≥88 m tall in September 2023. All trees are *Eucalyptus regnans* unless otherwise stated. All data were collected by tree climbing and compiled by the authors. Key information about the method, date and other notable features of the measurements is also listed.

distribution of remaining old-growth forests arising from accessibility, logging etc. For Tasmanian trees with trunk volume of ≥200 m^3, we examined allometric relationships between trunk volume and each of height, diameter at breast height and diameter at 10-m height, using scatter plots and correlation analyses. Using generalised linear modelling, we tested whether there was a difference between live and dead giant trees in the volume–diameter relationship.

Climate analyses

We extracted data to describe the climate envelope of Tasmanian and Victorian wet forests, and the climate of the specific locations of the tallest and most massive eucalypts. Gridded climatic means for the 1981–2020 period were obtained from CHELSA (Karger *et al.* 2017) at a resolution of 1-arc-second (approximately 700 m at the study-area latitude), for mean annual precipitation, mean annual temperature, and mean monthly climate moisture index (CMI). Values of these measures were extracted from the grids for the location of each tree. The Australian National Vegetation Inventory System (NVIS 4.1; Department of the Environment 2012) vegetation community polygons were cropped to the area of interest encompassing Tasmania, eastern Victoria, and a portion of south-eastern New South Wales near the Victorian border (MGA Zone 55, eastings 52,665–822,568, northings

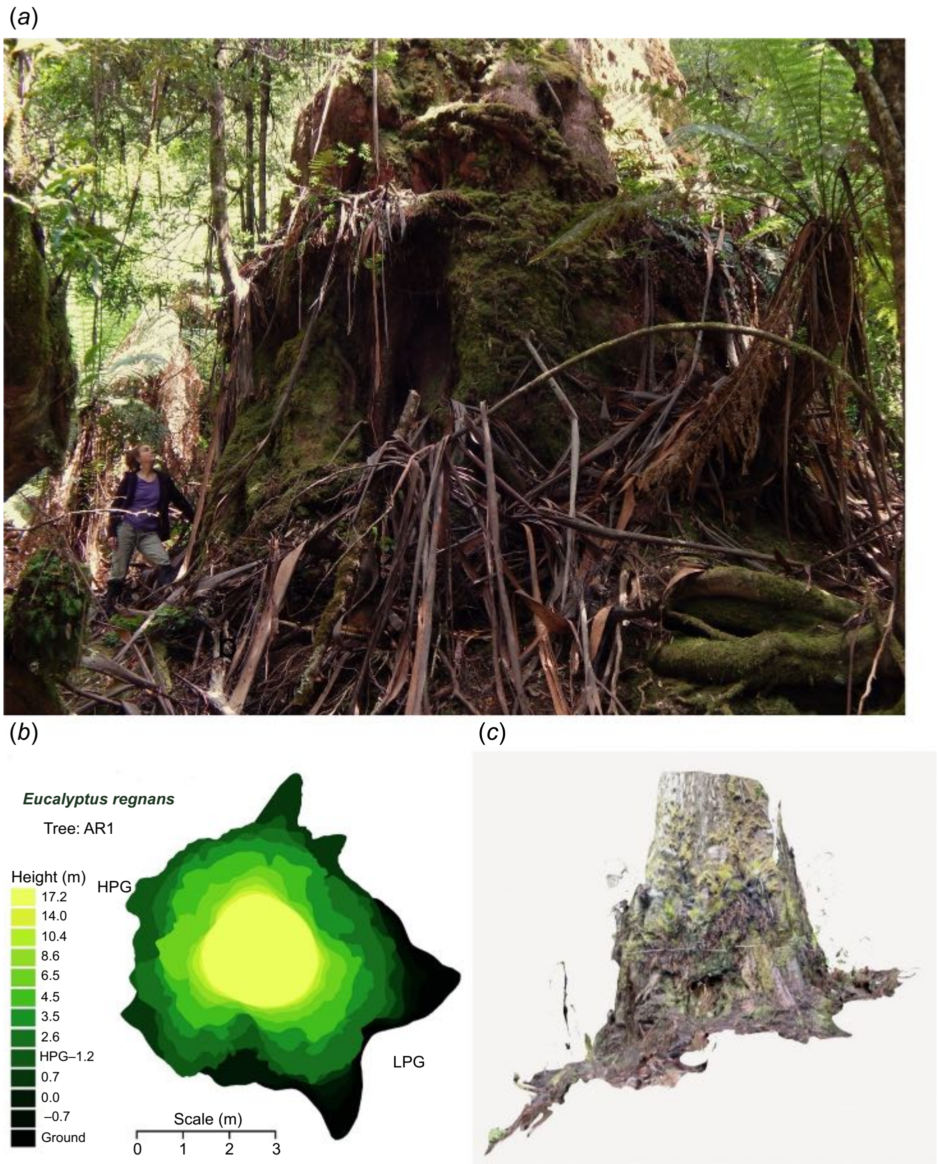

Fig. 1. An example of a massive tree (AR1, trunk volume 328 m^3). (*a*) The base of the tree with a person for scale (photo: B. Mifsud). (*b*) A base-map model, showing a series of horizontal cross-sections at various heights up the lower trunk, coloured according to height. (*c*) It is produced using photogrammetry or LiDAR scanning and allows a detailed volume estimate of the complex lower portion of the tree.

5,113,824–6,043,746). Vegetation classes were simplified into temperate rainforest (NVIS Code 1), wet forest (NVIS Code 3), and open forests (NVIS Codes 4, 5, 8, 28, 54 and 60) groups. Cell values for climate variables were extracted for each cell centre within these three aggregated vegetation types, and plots were produced, showing the distribution of identified trees and the broader vegetation polygons across these climate variables, for both tall and massive trees, and Tasmanian and Victorian trees.

We used generalised linear models to test whether there was a difference in climate between where tall and massive trees are located. We used the the following three climatic variables: mean annual temperature (MAT), mean annual precipitation (MAP) and CMI, which was calculated as precipitation (mm) – potential evapotranspiration (mm) (Hogg 1997). State (Victoria and Tasmania) was also included in these models. We also tested whether there was a difference in these climate variables between the locations of the recently dead Tasmanian trees that had previously been measured to have a trunk volume of ≥250 m^3 and their 11 counterparts that were still alive in 2022/23, acknowledging that there is potential autocorrelation in these data.

Fig. 2. Climbers in the process of measuring tree-trunk diameters by using the tape-wrapping method. (Photo: C. Hansen.)

Results

History of giant-tree measurement in Tasmania and Victoria

Most of the tallest and most massive eucalypts are found in south-eastern Australia, in the mainland state of Victoria and the island state of Tasmania (Williams *et al.* 2023). Since the mid-19th century, Victoria has developed a rich literature on its tallest (Caire 1905; Hardy 1911, 1921, 1923; Simpfendorfer 1982; Mace 1996; Bowman 2001; Mifsud 2003, 2012) and most massive (Hardy 1935; Mifsud and Harris 2016) trees. Unlike Victoria, which has numerous historical reports of very tall trees from a variety of districts (Caire 1905;

Cornthwaite 1925*a*, 1925*b*; Hardy 1935; Griffiths 1992), there are relatively few historical records of trees over 90 m tall being measured in Tasmania in the period from settlement to the early 1900s. Two blue gums (*E. globulus*), one at Mount Wellington and another on the Huon River, were recorded as being 101 m tall (Lewin 1906. A 97-m blue gum was recorded from about 1890 without listing a locality and a 94-m blue gum was recorded along the Huon Road in 1911. The recorded maximum heights are substantially greater in Victoria than Tasmania: superlative tree heights listed in Victoria range from a believable 114 m (Guinness World Records 2023*b*) to 143 m (Mace 1996). Last, all the tallest historical recorded trees in Tasmania were species of *E. globulus,* whereas all the historical tall-tree heights from Victoria were of *E. regnans* trees. Whereas there are only a few surviving photographs taken of very large trees in Tasmania from the mid-1800s to the early 1900s, the giant trees in photos from early colonisation in Tasmania appear no larger than trees currently known. This is unlike Victoria, where photographed trees of the mid- to late 1800s dwarf any trees alive now (Fig. 3). Possible explanations for the differences between the Tasmanian and Victorian records include the following: a greater interest in tall-tree measurements in Victoria in the late 1800s, spurred on by the influential botanist, Baron Von Mueller (Mace 1996); exaggeration by early colonists in Victoria; *Eucalyptus globulus* is a tree species that is more widespread and existed closer to colonial settlements in Tasmania and was the tree early settlers measured, rather than the more dense forest species, *E. regnans*; overestimations of tree height because of poor surveying techniques (or even recording rough height estimations as carefully measured 'facts'). Therefore, whereas the reported heights for historical Tasmanian trees are significantly lower than those often quoted from Victoria from the mid- to late 1800s, the accuracy of these earlier measurements cannot be verified. As Tasmania entered the era of industrial forestry, foresters would measure tree heights in designated coupes before they were logged and occasionally reported heights of very tall trees to the then Tasmanian Forest Commission. For example, in the late 1950s, the newsprint manufacturing company Australian Newsprint Mills (ANM) reported significant discoveries of tall trees in the following two locations in the Styx Valley: a 98-m tall *E. regnans* tree was measured in what is now known as the Styx Big Tree reserve, and a few kilometres to the east, at what is now known as the Andromeda reserve, 11 *E. regnans* trees were measured being >90 m tall, with the tallest of these being 98.7 m. These measurements were summarised by Mount (1960). In their paper 'Tasmania's Tallest Trees', Hickey *et al.* (2000) compiled data from an unpublished report by Kostoglou (2000). Before this, apart from Mount (1960), all formal measuring and recording of tall (or massive) tree data was unpublished and held by the Tasmanian Government Forestry department (Forestry Commission 1947–1994, Forestry Tasmania 1994–2016, Sustainable Timber Tasmania 2016–present) (Felton 2006). One such report recorded tree heights measured in the Styx and Florentine valleys by a registered surveyor, D. G. Potter, in October 1987 (Potter 1987). The tallest tree recorded there was a *E. regnans* 90.1 m tall, with no others recorded being >90 m. The same 90.1-m tree was remeasured and reported in the 2000 paper to be 92 m tall, but remeasurement via climber tape-drop in 2001 found that the tree was 87 m. This is a clear example of how evolving surveying techniques have affected tree-height measurement and, hence, cautions uncritical acceptance of historical measurements. Unlike the numerous measurements and reports of tall trees in Tasmania over the past seven decades, there has been little recognition of massive trees over that time. The only recorded measurements of a massive tree before the 1990s were from a specimen growing on Nicholls Spur near Junee, which was cut down by ANM for its paper mill in 1945. Once felled, measurements taken near the base and at various points along the fallen trunk indicate a trunk volume of approximately 330 m^3 (Helms 1945). From the accompanying photographs, the tree looked in excellent health and the cut trunk displayed no evidence of decay. Although not being quite as massive as the top four living trees measured in this study, it ranks in the top-10 most massive trees ever measured in Tasmania.

Tallest trees

The three tallest living trees were all *E. regnans* and measured 96 m tall; one had a live top and two had tops that were long dead (Table 3, also see figs 2, 10). The 96 m live-topped tree 'ED1', commonly known as 'Centurion', was discovered by LiDAR in 2008 and initially measured by climber-deployed tape drop to be 99.6 m tall. It was subsequently remeasured to be 99.82 m tall in 2018. Unfortunately, the tree was affected by the 2019 bushfires, and the tallest branches were damaged by ember attack at the junction, with the main trunk about 85 m above ground level, and subsequently fell. Tree 'AN1' was the tallest measured tree remaining in the Andromeda stand of tall trees in the Styx Valley. It was first climbed in 2005 and measured by tape-drop to be 97 m and appears to have lost a further metre of height in the intervening years. A further 17 trees were measured to be >90 m tall. All of these were *E. regnans*, except for a single specimen of *E. globulus,* which was 90.7 m tall. Both *E. obliqua* (88.5 m) and *E. tasmaniensis* (86 m) also had individual trees measured to exceed 85 m in height. The crowns of many of the tallest trees were unhealthy; 6 of the tallest 10 and 13 of the tallest 20 trees had dead or dying tops (Fig. 4). Most of the tallest trees were old; only one tree taller than 90 m was from a younger age class (Tree MR1, approximately 220 years old). A *E. viminalis* tree, listed as being 88.9 m tall by Hickey *et al.* (2000), was reported as unhealthy in 2016 (Wondermondo, undated), and dead by 2020 (Steane 2020), and was excluded from the current list.

Fig. 3. An example of a past giant tree from Gippsland, Victoria, from the late 19th century. The Bulga Stump was reported as being 10.7 m in diameter (111 feet girth) (State Library of Victoria 1914) and capable of holding eleven horses in its hollow base. Early settlers often lived their lives among the 'skeletons' of the burnt forest. Their very livelihoods relied on them being able to clear and farm the land where the former, centuries old forest stood. (Photo: Anon. 1914.)

Massive trees

The most massive tree measured was WH1, a *E. regnans* with a calculated trunk volume of 463 m^3 (Fig. 5, Table 4). That total would be over 480 m^3 when the main branches were added and would likely be above 490 m^3 if all wood from the smaller branches was included. A further seven trees exceeded 300 m^3 in trunk volume. Although five of these were *E. regnans*, both *E. globulus* and *E. obliqua* also produced individuals with a total wood volume greater than 300 m^3. Furthermore, we documented 32 trees with estimated trunk volumes of more than 250 m^3 and 116 trees exceeding 200 m^3. One tree with a girth of 18.5 m and an estimated trunk volume of 330 m^3 was logged in 1945.

Allometry of giant trees

Trunk volume of massive living trees was strongly correlated with diameter at 10-m height ($r = 0.83$) and weakly correlated with diameter at breast height ($r = 0.39$), but there was no correlation with height ($r = 0.10$) (Fig. 6). Diameter at 10 m height is strongly related to trunk volume (Fig. 5*b*) because it is largely free of the influences of irregularities, such as buttresses and burls, which can distort diameter measurements at breast height. Therefore, this index of stem diameter should be used in subsequent measurements of living and dead massive trees. Dead trees had significantly greater trunk volume ($P < 0.001$) for a given diameter at breast height than did living massive trees. The cause for this difference is unclear and may reflect geographic differences in tree shape associated with burned and unburnt areas, or variation in measurement of diameter at breast height, which is vulnerable to inaccuracies because of buttressing and sloping ground.

Landscape and vegetation correlates of tall and massive trees

Massive trees were evenly distributed among single-aged and multi-aged stands, whereas 85% of the tallest trees occurred in single-aged stands (Fig. 7). Massive trees were much more likely to have understoreys composed of rainforest species or a mixture of rainforest (fire-intolerant) and 'wet sclerophyll species' (fire-adapted) than were the tallest trees, for which the understorey was more likely to be a mix of wet sclerophyll species (Fig. 7) (Bowman 2000). There was no difference in slope between the tall and the massive trees. Aspect was more likely to be easterly than westerly for both massive ($P = 0.0003$, $n = 69$) and tall ($P = 0.02$, $n = 37$) trees (Fig. 8).

Many of the tall trees are concentrated in small stands, such as the Andromeda stand, where nine trees are currently recorded to be >90 m, the Manning Stand (1 tree >90 m tall and 4 >85 m) and the Three Huts stand (16 trees >85 m tall).

Fig. 4. Declining crown health of a giant *Eucalyptus regnans* tree in the Andromeda reserve Styx Valley. This small stand has 11 trees over 90 m in height, but all have dead or declining crowns. (Photo: Brett Mifsud.)

The remote McLeods Creek area also had 30 LiDAR hits of trees between 85 and 88 m tall, of which 10 have been confirmed by ground-based laser. These trees are believed to be in the 220-year-old age class, and most survived the December 2018 Gell River fire, which burnt through parts of the stand.

Climate envelope for giant trees in Tasmania and Victoria

Wet forest occurred in a climate space intermediate between the cooler wetter rainforest (found mostly in Tasmania), and the drier, slightly warmer open forest (Figs 9, 10, S2). There was no difference between tall and massive trees in the three climate variables MAT, MAP or CMI (Figs 10, S3). The Tasmanian giant trees occurred in areas that were, on average, significantly cooler (9.8°C vs 10.6°C MAT) and drier (1096 vs 1266 mm MAP) than those in Victoria, but with similar CMI (Fig. 11). Mean annual precipitation in the wet forest climate space mostly ranged from 800 to 1500 mm, mean annual temperature from 7.5°C to 12.5°C, and CMI from −20 to 100 mm (Fig. 11). Giant trees occurred through most of the wet forest climate space, although they were concentrated towards the

Fig. 5. Examples of the lower trunk of giant Tasmanian trees. (*a*) The lower 10 m of WH1, the largest tree by wood volume in Tasmania. (*b*) Tree SX1, the second-largest tree by wood volume. (*c*) Tree BM1, measured to 7.32 m in diameter (23 m girth), had the largest diameter (at 1.4 m height) of any measured tree in Tasmania. (Photos: B. Mifsud.)

cooler, wetter areas (Figs 10, 11). There was one outlier, a massive *E. obliqua* ('Mount Cripps', with 245-m^3 trunk volume), found in north-western Tasmania in an area that receives almost 2000 mm MAP.

Fire-killed trees

Fire is a major cause of mortality of giant trees. At least 18 trees with a trunk volume measured to be >250 m^3 have been killed by fire this century, including El Grande, which was killed by a forestry regeneration burn in 2004, and at the time was the world's largest known eucalypt (Table 5). Most giant-tree deaths were caused by wildfires, the most serious of which was ignited by dry lightning strikes on 15 January 2019. One large fire, the Riveaux Road Fire Complex, affected parts of the Southern Forests and was particularly damaging to older and larger trees. It killed 15 of the largest 25 trees known in the state at that time, including Rullah Longatyle, the world's largest *E. globulus* (Table 5). By contrast, during this period, logging is known to have killed only one massive tree, in 2012.

More massive trees than tall trees have been killed by fire in Tasmania since 2004. The fire-killed massive trees were from areas that were drier (1024 cf. 1101 mm MAP; $P = 0.01$), with a lower CMI (9.1 cf. 19.1; P = 0.0015), than areas supporting the live massive trees (Fig. S4). MAT was not significantly different between live and dead massive trees.

Discussion

Tasmanian giant trees are the tallest and most massive angiosperms on Earth (Sillett *et al*. 2015; Mifsud Harris 2016; National Register of Big Trees 2023*a*). These giant trees are concentrated in the south-eastern and central areas of the island, in the valleys of tributaries of the Derwent River (Upper Derwent, Florentine, Styx, Plenty), upper Huon River and Esperance River, with outlying isolated specimens

Table 4. Largest living Tasmanian trees ranked by trunk volume.

Tree ID	Volume of trunk(s) (m^3)	Volume of trunk(s) and main branches (m^3)	Diameter at 1.4 m (m)	Height (m)	Method of volume measurement	River catchment	Notes
WH1	463	n/a	6.14	70	Base model and tape wrap	Upper Derwent	Bifurcates at 57 m Located in 2021
SX1	358	386	7.10	77	Base model and tape wrap	Styx	Bifurcates at 16 m Located in 2002
FL1	352	378	5.10	84	Base model and tape wrap	Florentine	Bifurcates at 33 m Located in 2003
KE1	330	n/a	6.62	65	Lower girth and tape wraps	Kermandie	Severely burnt in 2019 Located in 2011
AR1	328	n/a	5.41	86.5	Base model and tape wrap	Arve	Escaped 2019 fires by 50 m
FL2	308	n/a	5.35	76	Lower girth and tape wraps	Florentine	
DN1	305	n/a	5.41	80	Lower girth and tape wraps	Denison	*Eucalyptus globulus* Located in 2021
SX2	296	337	5.42	53	Base model and tape wrap	Styx	*Eucalyptus obliqua*, bifurcates at 16 m
WH2	290	n/a	5.57	92	Girth and relaskop	Upper Derwent	Bifurcates at 46 m – only tree to be a giant in height and volume
HU1	288	n/a	6.04	83	Girth and relaskop	Huon	
AR2	285	n/a	5.79	81	Girth and relaskop	Arve	
KE5	280	n/a	6.39	56	Girth and relaskop	Kermandie	Trunk bole broken at 56
DN2	280	n/a	5.31	77	Girth and relaskop	Denison	Bifurcates at 50 m Located in 2022
SX3	278	291	4.58	81	Girth and tape wrap	Styx	Site of global tree sit in protests in 2003/2004
PC1	277	n/a	5.12	79	Base model and tape wrap	Picton	Lightly burnt in 2019
DN5	275	n/a	5.63	61	Girth and relaskop	Denison	*Eucalyptus obliqua* bifurcates at 22 m
AR3	275	n/a	5.19	72	Girth and relaskop	Arve	
PC2	270	n/a	5.38	60	Girth and relaskop	Picton	Escaped 2019 fires by 50 m
KE2	268	n/a	5.73	72	Girth and relaskop	Kermandie	Burnt in 2019
HP1	267	n/a	5.15	68	Girth and relaskop	Esperance	Located in 2010
HP2	265	n/a	4.49	85	Girth and relaskop	Esperance	
WH3	265	n/a	5.41	79	Girth and relaskop	Derwent	Remote location
HP4	260	n/a	5.73	50	Girth and relaskop	Esperance	Trunk broken at 47 m, located in 2023
DN6	260	n/a	5.14	65	Girth and relaskop	Denison	
BM1	260	n/a	7.29	76	Girth and relaskop	Huon	Located in 2022
MD1	260	278	5.09	60	Girth and relaskop	Tyenna	Located in 2014
HP5	260	n/a	6.08	65	Girth and relaskop	Esperance	Located in 2010
KE3	255	n/a	5.76	74	Girth and relaskop	Kermandie	Located in 2019
MD1	255	278	5.09	60	Girth and relaskop	Tyenna	Located in 2013
PC3	255	n/a	5.98	70	Girth and relaskop	Picton	Located in 2009
WH4	250	n/a	5.76	65	Girth and relaskop	Upper Derwent	Located in 2021

The wood volume of the trunk, and of the trunk with main branches, and the girth and height are listed for all known trees of $\geq$250 m^3, together with location in major river catchments. Stem branching is also noted. All trees are *Eucalyptus regnans* unless otherwise stated. The measurement method is listed, noting that the tape-wrap method is more accurate, because the visibility of the trunk and the accumulation of loose bark often impede accurate measurements with the relaskop method. All data are compiled by the authors via direct measurements as of September 2023.

occurring in localised areas in the north-west (Tarkine), including parts of north-east (Blue Tier) (Fig. 9). They all occur in a transition zone that includes mixtures of rainforest and tall wet eucalypt forests in high-rainfall areas (Fig. 9). The habitat for giant trees has not been as drastically reduced as in Victoria but they have been felled for timber and are increasingly vulnerable to fire kill (Lindenmayer *et al.* 2018; Bowman *et al.* 2022). Below, we elaborate on these points and make recommendations for Tasmania giant-tree conservation.

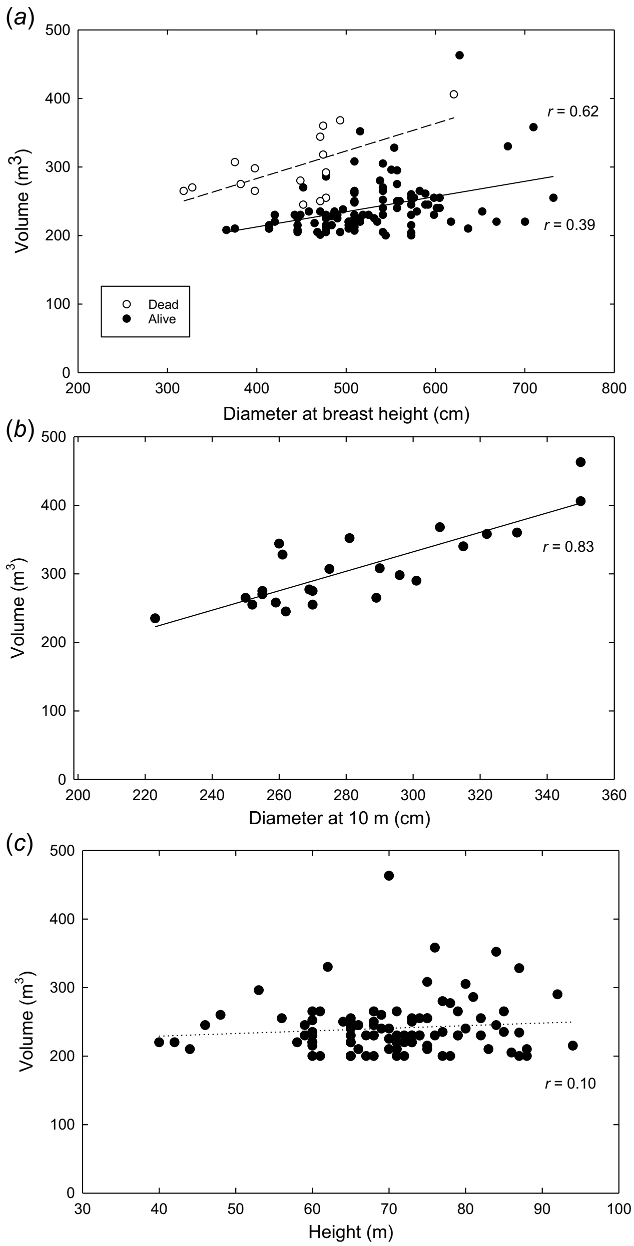

Fig. 6. Allometry of giant Tasmanian trees. Trunk volume of massive trees (≥200-m^3 trunk volume) in relation to (*a*) diameter at breast height (1.4 m) for dead and live trees, (*b*) diameter at 10-m height, and (*c*) tree height. Differences were significant ($P < 0.001$) between the live and dead trees.

Tallest Australian trees

Tasmania has six species with specimens that are either more than 70 m tall or 11.5 m in girth, namely, *E. regnans; E. globulus, E. obliqua, E. tasmaniensis, E. viminalis* and *E. dalrympleana*. Nearly all of the tallest and most massive trees are *E. regnans*. There are 19 Tasmanian trees taller than 90 m (18 are *E. regnans*), including the tallest known live-topped tree in Australia (the 96-m 'Centurion') (Table 3, Fig. 12*a*), and 41 taller than 87 m (38 are *E. regnans*). By comparison, the tallest known tree in Victoria is a 93-m-tall *E. regnans* originating from the 1926 bushfires, and a further five trees are known to exceed 90 m, (all *E. regnans*) (Mifsud 2012). Victoria also has three other species known to exceed 80 m tall, namely *E. cypellocarpa* at 85 m, *E. nitens* at 84 m, and *E. viminalis* at 80 m. Karri, *E. diversicolor*, is Western Australia's tallest tree, with the tallest known living tree a 78-m-tall specimen from the Shannon National Park (Du Guesclin 2024). There is disagreement as to which tree in New South Wales is currently the state's tallest tree. 'The Grandis', a *E. grandis* at Buladelah, has been measured to be 71 m tall, as has the Woodford tree, a *E. deanei* (National Register of Big Trees 2023*a*). There was also a specimen of *E. nobilis* located in Cunnawarra New South Wales that was measured to be 79 m tall in 1997 (New South Wales Government 2023). However, remeasurement is required because the time that has elapsed since it was measured and also because the tree was not measured by climber-deployed tape drop, laser or LiDAR. The tallest known tree in Queensland is 'Big Bob', a 72.8-m-tall *E. grandis* growing in the Sunshine Coast hinterland and found by LiDAR (Stumm 2012). No trees exceeding 70 m tall are known from South Australia, the Northern Territory, or the Australian Capital Territory (Supplementary Table S1).

Massive Australian trees

The Tasmanian *E. regnans* tree with a trunk volume of 463 m^3 is easily the largest known tree in Australia (Table 4, Fig. 5). In comparison, the largest *E. regnans* from Victoria measures only 245 m^3 (Table S2). There is also a *E. nitens* measured to be 229 m^3 and a *E. cypellocarpa* measured to be 163 m^3 from Victoria. (Mifsud and Harris 2016). In Western Australia, the largest measured trees are Tingle (*E. jacksonii*, 202 m^3) and Karri (*E. diversicolor*, 202 m^3) (Du Guesclin 2023). In New South Wales, the largest eucalypts by trunk volume include the 'Bird Tree' (*E. pilularis*, 155 m^3) and 'The Grandis' (*E. grandis*, 137 m^3) (R. Du Guesclin, pers. comm.). Whereas these are all species of *Eucalyptus*, contenders for the title of the largest trees in New South Wales and Queensland are members of the genus *Ficus*. Impressive individual trees include the 'Temple Fig', *Ficus virens*, near Murwillimbah, 'The Curtain Fig' and 'Cathedral Fig' from the Atherton tablelands and a Moreton Bay Fig, *Ficus macrophylla*, growing near Bellingen (National Register of Big Trees 2023*a*). Although these fig trees have huge girths owing to their extensive plank buttresses and coalesced roots, they do not contain wood volumes comparable to the largest eucalypts. This is due to a combination of factors, including the enormous amount of air contained between the plank buttresses and the basal and aerial roots, the fact that these buttresses extend high up the trunk and thus the trunks never become round, and in some examples of 'strangler' figs, there is no actual 'trunk', just a vast entanglement of aerial roots. Thus, making a volume

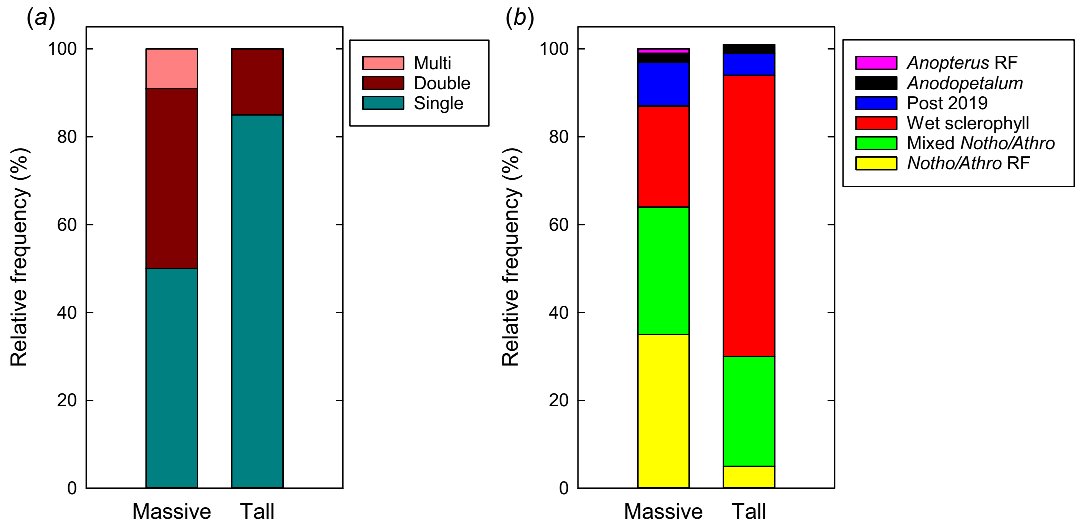

Fig. 7. Characteristics of giant Tasmanian trees and associated vegetation. Comparison of massive and tall trees in relation to (*a*) relative frequencies of single-, double- and multi-aged stands, and (*b*) understorey vegetation types.

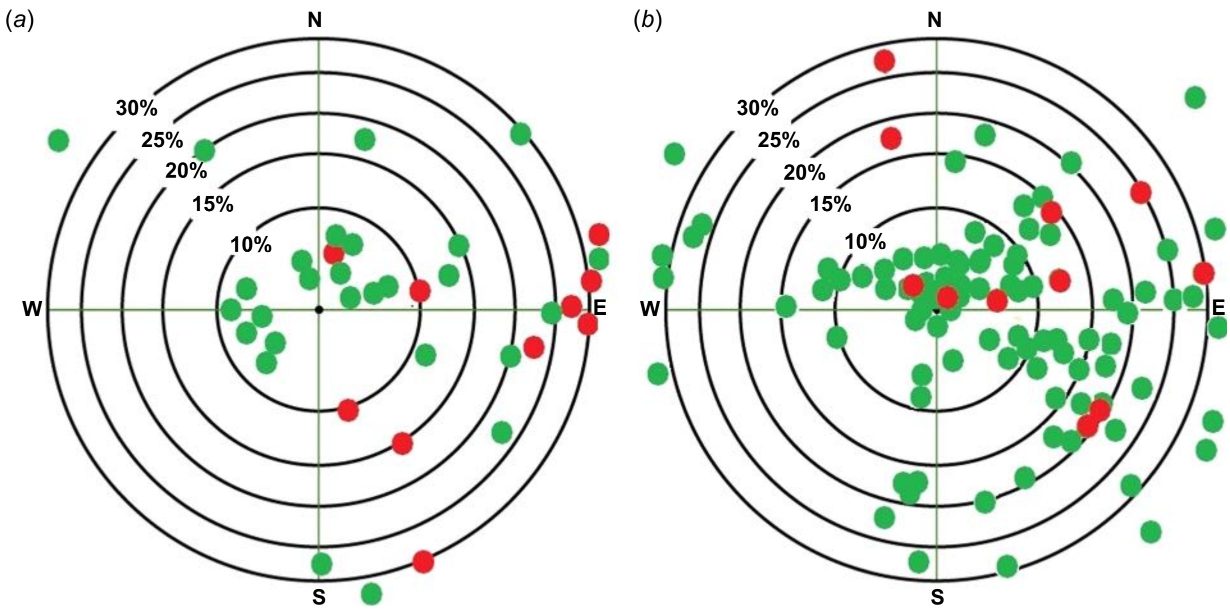

Fig. 8. Distribution of Tasmanian giant trees in relation to slope and aspect. Circular plots of aspect and slope (%) for (*a*) tallest, and (*b*) most massive trees. Red indicates the top 10 trees in each category (most massive or tallest).

estimate on these trees is extremely difficult, but it is likely that the largest specimens contain wood volumes close to 200 m^3. There are no individual trees known to exceed 100 m^3 in wood volume in South Australia, the Northern Territory, or the Australian Capital Territory.

Global comparisons

On the basis of the height of the tallest extant individuals, *E. regnans* was, until 2020, in second place on the list of the world's tallest tree species. However, 'Centurion' has since lost height and is now 96 m tall, so *E. regnans* currently ranks sixth on the list of the world's tallest living tree species, behind the coast redwood (*Sequoia sempervirens*, 115.92 m), Himalayan cypress (*Cupressus gigantea* – a 102.3-m specimen was recently discovered in China) (Fangyu 2023), sitka spruce (*Picea sitchensis*), Douglas fir (*Pseudotsuga menziesii*), (all conifers) and a tropical species, *Shorea faguetiana*, from Danum Reserve, Sabah, Malaysia, which currently measures 98.53 m (Shenkin *et al.* 2019). The 90.7-m-tall *E. globulus*

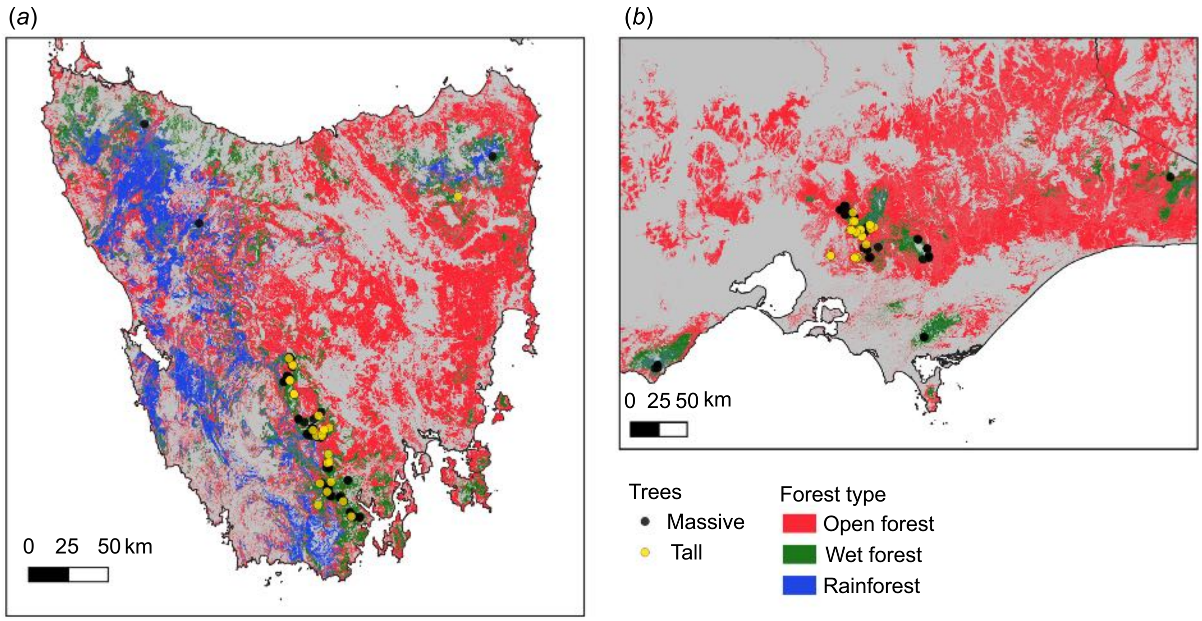

Fig. 9. Geographic distribution of Tasmanian and Victorian giant trees. Locations of tall trees (≥85 m tall; yellow circles) and massive trees (≥200-m^3 trunk volume for Tasmania, 170 m^3 for Vic; black circles) in (*a*) Tasmania and (*b*) Victoria (because there were only 14 Victorian trees with a trunk volume of ≥200 m^3, we used a lower-volume threshold). Measurements were confirmed by ground-based laser and or climber-deployed tape drop. The distribution of wet eucalypt forest is shown in green, open eucalypt forest in red and cool temperate rainforest in blue.

ranks eighth and the 88.5-m-tall *E. obliqua* ranks 11th in list of the world's tallest living tree species. The most massive known trees on the planet are giant sequoias, *Sequoiadendron giganteum*, from the western slopes of the Sierra Nevada ranges, California. The largest known giant sequoia, 'General Sherman', has a calculated trunk volume of 1395.2 m^3 (Sillett *et al.* 2021). The only other tree species known to exceed 1000 m^3 in trunk volume is the coast redwood, *Sequoia sempervirens*, which occurs in a 750-km strip from central California to southern Oregon, with the largest measured tree at 1083.7 m^3 (Sillett *et al.* 2022). In terms of age, giant sequoia trees can live in excess of 3000 years and coast redwoods to beyond 2000 years (Sillett *et al.* 2021), whereas it is unlikely that *E. regnans* can live much beyond 600 years (see below). Another tree from the Pacific Northwest, the western red cedar, *Thuja plicata*, attains sizes comparable to the largest *E. regnans*, with the largest living specimen listed to be 449 m^3 (Van Pelt 2001). The three Pacific Northwest species listed above are all conifers, whereas *E. regnans* and the other large eucalypt trees are angiosperms. The largest eucalypts are probably the world's largest known angiosperms as measured by trunk volume and wood mass. Their nearest rivals are baobab trees in southern Africa, *Adansonia digitata*, and Madagascar, *Adansonia grandidieri*, the largest of which has been recorded to have a stem volume of 414 m^3 (Guinness World Records 2023*a*). However, the 'wood' of a baobab is fibrous, 70% water and very soft, and of low density (about 130 kg m^{-3}, compared with 680 kg m^{-3} for *E. regnans*; Guinness Book of Records), so that the largest baobabs contain much less biomass than do the largest eucalypts. The largest eucalypts are also likely the to be the largest-trunked trees in the southern hemisphere, their main rival being the New Zealand kauri, *Agathis australis*. The largest extant kauri tree, named 'Tane Mahuta', Māori for 'Lord of the Forest', has been measured to have a trunk volume of between 255 m^3 and 317 m^3, depending on what part of the tree is included as 'trunk' (Earle 2023; R. Van Pelt, pers. comm).

Ecological correlates of Tasmanian giant-tree height, volume, and age

We found that tall and massive trees are restricted to the same climate envelope and show no differences in aspect. Our allometric analysis showed that variation in trunk volume was driven by variation in the diameter of the stem above the basal buttressing, rather than by tree height. As outlined below, we suspect the differences in height and volume are controlled not by the physical environment, but rather are influenced by stand dynamics and stand age. This hypothesis is supported by the observation that the tallest trees are typically in single-aged stands with a wet sclerophyll understorey, whereas massive trees more often occur in multi-aged stands with rainforest understoreys. Tasmanian giant trees occur in wet eucalypt forest, predominantly in areas receiving between 1000 and 1500 mm MAP, noting that the water balance of sites that support giant trees is affected by

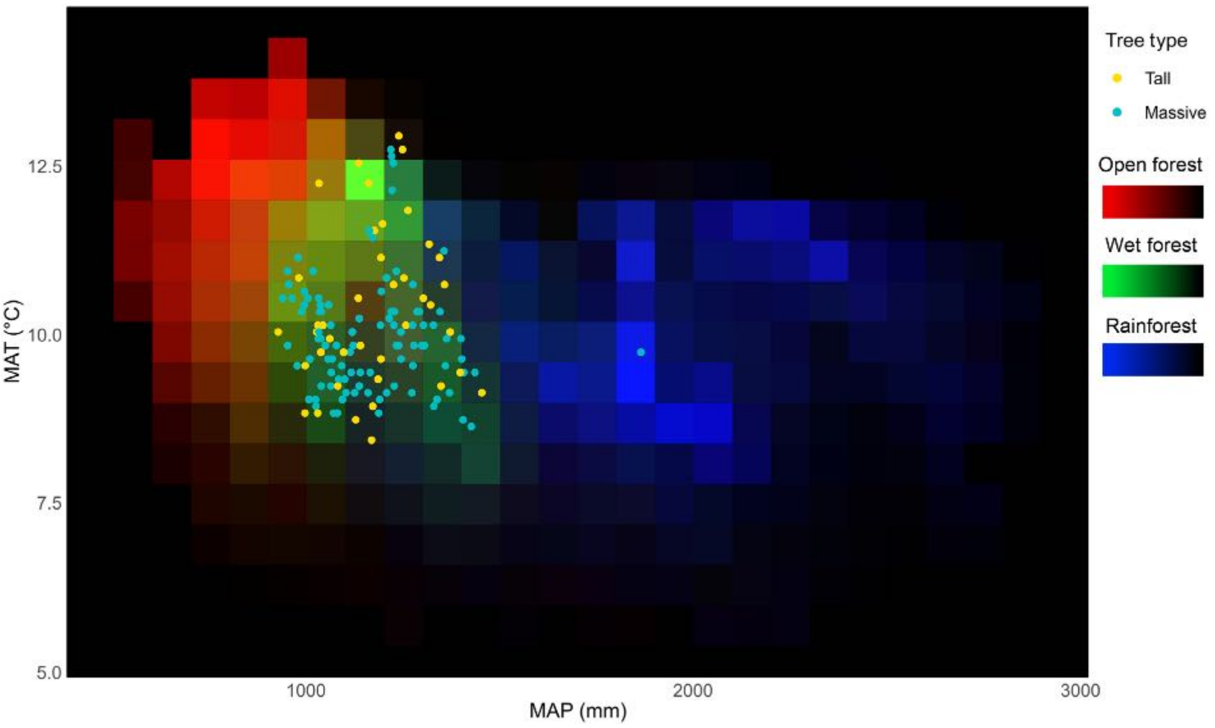

Fig. 10. Distribution of Tasmanian and Victorian giant trees in climate space. Climate of locations of tall (yellow dots) and massive (teal dots) trees in relation to the climate envelope of wet eucalypt forest (green pixels), open eucalypt forest (red pixels) and rainforest (blue pixels) in Tasmania and Victoria. The intensity of the colour in each pixel is proportional to the area of that vegetation type represented by that MAT/MAP combination; for example, the most common climate for a wet forest is MAT of 12–12.5°C and 1100–1200 mm MAP. Tall trees are all Tasmanian and Victorian trees ≥85 m tall and massive trees are all live Tasmanian trees with a trunk volume of ≥200 m^3 and Victorian trees of ≥170 m^3. Because there were only 14 Victorian trees with a trunk volume of ≥200 m^3, we used a lower-volume threshold. The outlier is a massive *Eucalyptus obliqua* tree in north-western Tasmania. Frequency histograms showing the areas of open eucalypt forest, wet eucalypt forest, and rainforest separately for Tasmania and Victoria are presented in Fig. S2.

slope, aspect and elevation. It is easy to explain the drier limit by the large amount of water required to grow and sustain such large trees. Likewise, moisture stress is likely to explain why an easterly aspect was favoured by the giant trees, which would lessen the amount of incoming solar radiation during the hottest part of the day. However, the reason that wet eucalypt forest tends not to occur in the wettest areas is less obvious. We suspect that this can be explained by the fire ecology of these forests; germination and establishment of the giant eucalypt species requires disturbance, usually fire. Without fire, over a time-scale of centuries, the more shade-tolerant rainforest species eventually dominate the understorey, and there is a transition to mixed forest and eventually rainforest (Gilbert 1959; Jackson 1968; Bowman 2000). Gilbert (1959) and Ashton (1976, 1981) established the concept that major fire events in wet forest dominated by *E. regnans* and other obligate-seeder eucalypts produce predominantly single-aged stands. However, this paradigm has been challenged by more recent research, indicating that multi-aged stands are reasonably common in tall wet eucalypt forest (McCarthy and Lindenmayer 1998; Turner *et al.* 2009; Prior *et al.* 2022). Here, we found that 85% of the tallest trees occurred in single-aged stands, whereas the massive trees were evenly distributed among single-aged and multi-aged stands. This may reflect the following: (i) high intensity, stand-replacing fires often lead to a very high density of eucalypt seedlings that face extreme competition for light, and the tallest-growing trees are more likely to survive to maturity (Givnish *et al.* 2014; Sillett *et al.* 2015); (ii) the extreme age of the largest trees increases the likelihood that they have survived at least one fire event in their lifetime, which can stimulate eucalypt seedling germination; this increases the chance of them being in a multi-aged stand; and (iii) fire events can damage the crowns of tall trees, so even if the tree survives the fire, crown dieback means it is often no longer extremely tall. This can either be by flames affecting the crown of the tree, or indirectly, by affecting the base of the tree or via embers lodging and structurally damaging the tree higher up the trunk (for example, with the 'Centurion' tree). The fact that the understorey of massive trees was more likely to contain rainforest species, whereas tall trees were more likely to have wet sclerophyll species in their understorey, is best explained by the differences in age classes between the two groups. The reasoning here is

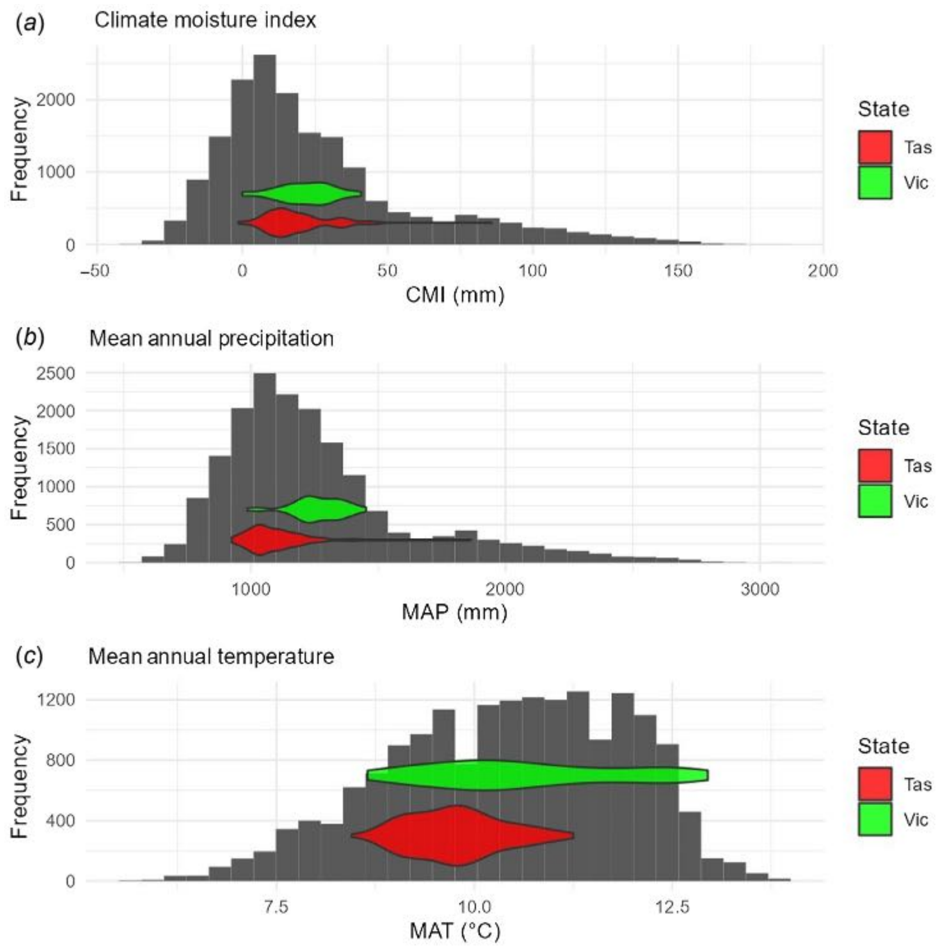

Fig. 11. Occurrence of giant Tasmanian and Victorian trees relative to the climate space of mapped wet forest. Black histograms show frequency distribution of (*a*) climatic moisture index (CMI), (*b*) mean annual precipitation (MAP), and (*c*) mean annual temperature (MAT) for wet forest in Tasmania and Victoria. Violin plots show the distribution of giant trees in Tasmania (red) and Victoria (green). There was no difference in climate between exceptionally tall (≥85 m) and massive (≥200 m^3 for Tasmania, ≥170 m^3 for Victoria) trees; so, they have been combined in this figure.

that for the giant trees to reach such sizes, they must have avoided fire for a long period, allowing the rainforest species to slowly colonise, become dominant and replace the wet sclerophyll species by shading them out (Gilbert 1959). In Victoria, it has been shown that the largest trees are mostly found near cool temperate rainforest and cool temperate mixed forest on streamlines (Trouvé *et al.* 2024).

On the basis of dendrochronology of rainforest trees and ^{14}C dating of giant eucalypt stems, the largest trees are likely to be 450–500 years old (Hickey *et al.* 1999; Wood *et al.* 2010), whereas most of the tallest trees come from estimated age classes in the 220–350-year range. It is important to note here that dendrochronological techniques do not work well with eucalypts because of their wood anatomy, especially for older stems that are often hollowed out from rot, fire damage or both (Brookhouse 2006). Sillett *et al.* (2015) used a different approach to determine age through the measurement of a series of *E. regnans* trees of various known age classes from 90 to 300 years old. Via the development of allometric equations quantifying increases in annual wood volume growth, they estimated the age of three significant Tasmanian giant trees as follows: FL1 at 430 years (95% CI 360–500), ED1 at 320 years (95% CI 260–380) and the deceased El Grande at 480 years (95% CI 400–560).

Most of the 25 tallest trees in Tasmania are estimated to be between 320 and 500+ years old. Only 1 of the 19 trees taller than 90 m as measured was from the 220-year-old age class that was once common throughout much of the Florentine Valley. This tree is from the very small Manning Reserve (alternatively known as Hunns Creek) in the northern part of the valley. A further four trees from the Three Huts Reserve (also a stand of 220-year-old trees located in the Florentine Valley) were between 88 and 89.5 m tall, with a further 12 exceeding 85 m in height (Fig. 12*b*). On the basis of previous

Table 5. The 18 most massive Tasmanian trees recently killed by fire.

Tree name	Volume of trunks (m^3)	Diameter at 1.4 m (m)	Height (m)	Volume of trunks and main branches	Measurement method	Year and cause of fire
El Grande	406	5.98	79	435	Base model and Barre and Stroud	Forestry regeneration fire 2004
Rullah Longatyle (*E. globulus*)	368	5.41	81	n/a	Base model and Criterion laser	Wildfire 2019
Arve Big Tree	360	5.47	87	n/a	Base model and Criterion laser	Wildfire 2019
Bigfoot	344	6.53	83	n/a	Base model and tape wraps	Wildfire 2019
Master Bennetts	318	5.76	81	n/a	Base model and Criterion laser	Collapsed 2021 following wildfire 2019
Swearing Bobs Beast	292	5.28	61	322	Base model and tape wraps	Wildfire 2019
Wayatinah Giant	307	5.41	86	n/a	Base model and Criterion laser	Collapsed 2017 following wildfire 2010
Hopetoun Link Hulk	290	5.79	47	n/a	Girth and tape wrap	Wildfire 2019
Wayatinatoo	281	5.21	79	n/a	Girth and Criterion laser	wildfire 2010
Elder Bennetts	275	4.93	78	285	Girth and tape wrap	Wildfire 2019
Swirly Burly Megs	270	6.11	60	n/a	Girth and relaskop	Wildfire 2019
Coodabeen Champ	270	4.77	86	n/a	Girth and tape wrap	Wildfire 2019
Baron Bennetts	265	5.41	65	n/a	Girth and tape wrap	Wildfire 2019
The Prefect	265	6.04	73	n/a	Girth and relaskop	Wildfire 2019
Bullants Revenge	260	5.25	86	n/a	Girth and realskop	Wildfire 2019
Friar Bennetts	260	5.73	65	n/a	Girth and relaskop	Wildfire 2019
Bobdozer	255	5.15	82	n/a	Girth and relaskop	Wildfire 2019
Toby Bennetts	250	5.6	79	n/a	Girth and relaskop	Wildfire 2019

The tree name, trunk and total volume, diameter, height, measurement method and date and type of fire are listed. Trees are all *E. regnans* except where indicated. Note: the Nicholls Spur Giant, logged in 1945, had a diameter of 5.89 m and an estimated trunk volume of 330 m^3. It was one of the very few giant trees with a volume precisely measured before the year 2000.

studies on 300-year-old *E. regnans* trees in Victoria (Sillett *et al.* 2015), these 220-year-old trees could continue to slowly grow in height as long as their upper trunks remain intact. Thus, there are a few very tall trees in the 200–220-year age-bracket that could potentially produce trees up to 100 m tall in the next 50–100 years, to replace the current tallest but older and declining trees with dead or broken tops (Fig. 4). However, the situation for giant trees is very different. This is because the 220-year-old trees mentioned above, although very tall, have trunk volumes of only 40–80 m^3. Modelling from Sillett *et al.* (2015) indicates that although volume increments can increase with age in a healthy *E. regnans* tree, for a 220-year-old tree to grow from 80 m^3 to 300 m^3 in volume will take from 200–260 years, and getting to 400 m^3 will take 260–340 years. In summary, there is evidence *that E. regnans, E. obliqua, E. globulus* and *E. tasmaniensis* can live up to 500 years or more. However, it is unclear whether the very largest living trees in Tasmania are survivors from a distant fire event more than 600 years ago or are super-sized outliers from a fire event approximately the year 1500 (Fedrigo *et al.* 2019). Further study using radiocarbon dating of charcoal deposits in the soil around some of the largest living trees may further extend the known life expectancy of wet forest eucalypts well beyond 20th century estimates.

The age a tree species can attain is limited by the investment a tree makes into bark protection and heartwood defence. In an extreme example, the giant sequoia (*Sequoiadendron giganteum*) from the Sierra Nevada, California, reaches ages in excess of 3000 years because once a tree reaches a certain size, the combination of its extremely thick bark and insect- and rot-resistant heartwood effectively eliminate most potential threats such as fire, insect attack and fungal decay (Sillett *et al.* 2021). In comparison, *E. regnans* has very thin, smooth bark above its basal stocking and thus is easily killed by fire, as well as heartwood that is extremely susceptible to fungal attack, which leads to catastrophic, rot-induced structural failure in its later years as well as creating entry points for fire (Mifsud and Harris 2016). Consequently, *E. regnans* (and most other eucalypts) cannot attain the extremely old ages listed for some conifer species.

Wildfire mortality

Very old and large eucalypts are especially vulnerable to fire because typically they contain pre-existing fire scars, areas of rot and multiple hollows that burn very readily (Mifsud and Harris 2016). The main cause of death of the largest

Fig. 12. Examples of exceptionally tall Tasmanian trees. (*a*) Tree ED1, the tallest living tree in Tasmania, photographed in 2008 when still intact at 99.6 m. Note that the bole is covered with epicormic growth, usually a response to past crown damage. (*b*) Tree TH4, an 88-m-tall, 220-year-old tree in Three Huts Reserve, Florentine Valley. (Photo: B. Mifsud.)

Tasmanian trees in recent decades has been fire (Bowman *et al.* 2022). Here, we recorded high mortality of giant trees following the 2019 fires. Although these fires occurred during a pronounced drought that coincided with above-average summer temperatures (Wardlaw 2022), the forest fire-danger index was only low to moderate (Prior *et al.* 2022). We note that survival rates of the wet forest eucalypts in the 50–120-cm-diameter classes were between 80% and 95% following the fire, reinforcing the point that individuals in the 40–150-year-old age class typically survive lower-intensity fires. In addition to fire intensity and tree size, species is a crucial determinant of survival; *E. regnans* is the most vulnerable, being an obligate seeder, with very limited resprouting capacity (Waters *et al.* 2010), whereas *E. obliqua* can resprout both epicormically and basally (Trouvé *et al.* 2021; Prior *et al.* 2022). *E. tasmaniensis* (formerly *E. delegatensis* subsp. *tasmaniensis*) is a resprouter (unlike its mainland close relative, *E. delegatensis*, an obligate seeder), and has intermediate fire tolerance (Rodriguez-Cubillo *et al.* 2020). Recognising that fire is the main danger to the existing largest trees, we advocate developing a triage plan to protect the tallest and most massive trees. This would involve fire-behaviour modelling to identify landscape settings that are least fire prone, combined with field surveys to identify individuals most likely to survive fire. This would inform practical measures such as such as removing ground-surface fuels, wrapping trees in aluminium foil and irrigation (Bowman *et al.* 2022).

Climate change and fire

Our climatic analysis showed that the fire-killed giant trees were in areas that were, on average, significantly drier than those where the surviving giant trees occur. This accords with Victorian research showing that surviving giant trees are strongly associated with mesic vegetation such as rainforest

(Trouvé *et al.* 2024). Although acknowledging these data are spatially autocorrelated, one would expect the warmer, drier parts of the wet eucalypt forest range to be most at risk from increased fire frequency and severity. Given enough time, if fire frequency increases, the wet forests could potentially expand into areas of what is currently rainforest. However, the rapidity of climate change combined with the long lifespans of these species, their slow dispersal rate and the fragmentation of the remaining wet forest mean that this is unlikely to occur. In addition to exacerbating the severity and frequency of wildfire, climate change poses a direct threat to giant trees by increasing temperatures and therefore evapotranspiration and drought stress (Lindenmayer and Laurance 2017). Maximum tree height represents a balance between hydraulic limitation and allocational allometry (Givnish *et al.* 2014), and globally, most forest species operate within narrow hydraulic safety margins (Choat *et al.* 2012). Therefore, large, old trees are likely to be particularly vulnerable to rising temperatures, because they established under, and are adapted to, a milder climate than that projected for the future (Fox-Hughes *et al.* 2014; McDowell and Allen 2015). Indeed, large trees were the most likely to die during an experimentally imposed 10-year drought in a tropical rainforest (Rowland *et al.* 2015). Tall trees experience greater hydraulic stress than do shorter ones, and stomatal limitation of photosynthesis was found to increase with height of *E. regnans* trees between 61 and 92 m tall in Victoria and Tasmania (Koch *et al.* 2015). Catastrophic failure of the hydraulic system is a major cause of tree mortality during drought (Rowland *et al.* 2015; Choat *et al.* 2018). Prolonged drought stress has apparently already led to the deaths of the tallest known *E. viminalis* trees (including one of ~89 m tall) in eastern Tasmania in the late 2010s (Steane 2020). The adverse effects of drought on trees can persist for years, because trees need to repair their water-transport system by regrowing damaged xylem, and the number of years required for recovery increases with tree size (Trugman *et al.* 2018; Arend *et al.* 2022). Of concern is the poor crown health of many of Tasmania's giant trees, such as those in the Styx Valley (Fig. 4). Effects of future droughts will be worsened by increasing temperatures (Choat *et al.* 2018). In addition, hotter conditions could limit the size attained by wet forest eucalypts in the future. A prolonged, unusually warm period was shown to switch a tall *E. obliqua* forest from a carbon sink to a carbon source (Wardlaw 2022), and warmer temperatures disproportionately reduce the growth rate of large eucalypts relative to smaller ones (Prior and Bowman 2014).

Historic loss of giant trees: the case of *E. regnans*

Our study has shown that Tasmanian *E. regnans* old-growth forests contain the Earth's largest flowering trees. This is despite *E. regnans* forests occupying a relatively small area of Tasmania, with an estimated current extent of 76,050 ha (Tasmanian Government 2023*b*), compared with approximately 100,000 ha pre-1750 (Resource Planning and Development Commission 2002). A question arises whether there are fewer and smaller trees in Victoria as a consequence of historical logging and land clearance. Historical reconstruction suggests that before European colonisation, there were ~250,000 ha of *E. regnans* old-growth forest in Victoria, but land clearing, logging and extreme bushfires since European settlement have drastically reduced the extent of old-growth *E. regnans* to less than 1.16% of its pre-1750 extent (Lindenmayer *et al.* 2021). Although this estimate hinges on definitions of old growth. A more inclusive definition, such as including stands of trees >120 years old (e.g. Trouvé *et al.* 2024), would increase this amount. However, expanding the definition has no effect on the estimated area where the oldest and largest trees occur (i.e. >400 years old, >200 m^3) (Table 4). The Tasmanian forests have suffered considerably less from land-clearing for farming, although some *E. regnans* wet forests have been converted to plantations of *Pinus radiata* and *E. nitens* (Tasmanian Government 2022). The remaining areas of very old *E. regnans* forest indicate that fires have been less destructive than those in Victoria (Hickey *et al.* 1999, 2001), possibly reflecting a generally cooler, moister climate in Tasmania (Fig. 11).

The largest living Tasmanian *E. regnans* trees appear to be close to, if not equal, in size to the very large *E. regnans* trees depicted in photos from Victorian forests of the Otway and Strzelecki Ranges from the late 1800s to early 1900s (Peirce and Cunningham 1888; Holmes 1949; Griffiths 1992). Although diameter measurements from that time significantly exceed that of any eucalypt alive today (see Fig. 3), the photographs that survive mostly depict the lower 5 m or so of the base of the tree, and consequently the size of the bole above that is not known. Because the correlation between diameter at breast height and wood volume is poor, the trunk volume of these giants of the past is uncertain. However, from the size of the bases alone, some of these trees would have surpassed 350 m^3 in trunk volume.

Conservation of Tasmanian giant trees

Indigenous management

The great age of extant giant trees, which established several centuries before European colonisation, combined with the 35,000-year-old history of Tasmanian Aboriginal peoples (Cosgrove 1999) leaves no doubt that Aboriginal fire management was favourable for the development and persistence of old-growth tall eucalypt forests. Furthermore, the disruption of Aboriginal fire management, which adversely affected long-lived rainforest and montane species such as *Athrotaxis selaginoides* and *A. cupressoides* (Holz *et al.* 2015, 2020), is likely to also have affected giant eucalypts, although the extent of this impact is uncertain. It is possible that Aboriginal people used low-severity fires, which cause little damage to tall eucalypt species (Prior *et al.* 2022), to maintain access through some areas of wet forests and rainforests. We are unaware of recorded use of Aboriginal landscape burning to protect old-growth wet eucalypt forest, but this topic deserves further historical and cultural investigation (Cosgrove 1999; Holz *et al.* 2015, 2020; Lindenmayer and Bowd 2022; Lester *et al.* 2023).

Logging and clearing

Logging and conversion to plantations have been a major threat to the survival of giant Tasmanian trees and the broader vegetation types that have supported them. An unknown but substantial number of trees over 85 m tall and over 280 m^3 in trunk volume would have been logged between the 1940s, when large-scale, clear-cutting of Tasmania's forests began, and when Forestry Tasmania implemented their tall- and giant-tree protection policies in 1999 and 2003 respectively. For example, the total area of all *E. regnans* forest declined 10.3% during the years 1996–2001 and a further 5.5% between 2001 and 2006 (Tasmanian Government 2006), largely owing to the replacement of native forest by *E. nitens* plantations. Significantly, this loss has slowed; since 2015, losses have been only 0.2% (Tasmanian Government 2022). The overall area of old-growth wet forest lost since 1996 (comprising all of the species *E. regnans, E. obliqua, E. tasmaniensis, E. viminalis* and *E. globulus*) is estimated to be 10.6%. Importantly, most old-growth wet forest is now within the reserve system (Tasmanian Government 2022). It is critical to protect large areas of wet eucalypt forest, both old growth and regrowth, to maximise the chances of individual trees and indeed large stands of trees becoming very tall or large in the future (Lindenmayer *et al.* 2018).

Giant-tree conservation estate

The most recent State of the Forest report estimated that there is 66,000 ha of *E. regnans* forest remaining in all age classes, a loss of ~10,000 ha since 1996. In terms of conservation of wet forest species across Tasmania, 27% of *E. regnans*, 19% of *E. obliqua*, 22% of *E. tasmaniensis*, 21% of *E. viminalis* forest and 11% of *E. globulus* are currently (in 2022) protected in the National Reserve System (Tasmanian Government 2022). As of July 2023, all the 25 tallest trees and 23 of the 25 most massive trees found in this study are protected, either in designated giant-tree zones within State Forest land managed by Sustainable Timber Tasmania, or within areas managed by Parks and Wildlife, many in the Tasmanian Wilderness World Heritage Areas (TWWHA) (Tasmanian Government 2024). Virtually all the most massive and tallest trees now included in the TWWHA were once in State Forest land. For example, in 1992 only 6.4% of old-growth *E. regnans* forests were in reserves (Australian Government 1997), and even in 2006, 90% of the designated giant trees were still in State Forest land and, although 'protected', they were still vulnerable to indirect threats from harvesting and regeneration burns in adjacent logging coupes (Herrmann 2006). The reservation of a significant proportion of tall, wet forest in Tasmania has occurred only after numerous long, and sometimes bitter battles between conservationists and the managers of the government owned forests and the associated logging industry (Dargavel 1995; Ajani 2007; Beresford 2015). Without such conservation efforts, most of the largest known trees in the southern hemisphere, including the largest, would likely have been logged years ago.

Recognition of giant trees for conservation

The way tall and massive trees have been recognised, and, in turn, been protected from forestry operations has varied substantially over time. In 1945, ANM noted a tree of outstanding size (Helms 1945), but logged it anyway. However, in the 1950s and 1960s, they created several small informal reserves in their large wood concessions in the Florentine and Styx valleys. These included the Andromeda (6.5 ha) and Styx Big Tree (15 ha) reserves in the Styx Valley, which were specifically created to conserve some very tall *E. regnans* trees. Other small reserves in the Florentine Valley, such as Lawrence Creek (15 ha), Lady Binney (50 ha), Manning Road/Hunns Creek (17 ha), Pagoda (7 ha) and Three Huts (20 ha), were primarily set aside to showcase representative samples of the original forest prior to logging, and not specifically to conserve trees of outstanding height or size (Kostoglou 2000). Nevertheless, the Three Huts and Manning reserves, despite their small size, contain the best examples of very tall trees from the 220-year age class (Fig. 13). However, it is important to note that none of the ANM reserves listed above contains any of the 50 largest-volume trees in the state. Another example where a giant tree was identified, conserved and showcased concerns the Arve Giant. First measured by district surveyors when planning a logging road in the 1980s (Kostoglou 2000), it was spared from future logging and had a walkway constructed to it, as well as having the road to it sealed for safer public vehicle access. Unfortunately, the Arve Giant was burnt and collapsed following the 2019 fires (Ogilvie 2019; Table 5).

In 1994, the Tasmanian Forestry Commission was rebranded Forestry Tasmania, with a statutory duty to optimise both economic returns and benefits from non-wood values (Dargavel 1995; Felton 2006). Belatedly, in 1999, a formal policy of protecting tall trees on state forest land was introduced where all trees measured 85 m and above would be excluded from logging and given a buffer protection zone from any forestry operations (Whitely 2018). However, the accidental killing of the then largest ever known tree in Tasmania 'El Grande', in a forestry regeneration burn in 2003 (The Age 2003), an event which made news overseas (British Broadcasting Corporation 2003), led Forestry Tasmania to introduce a policy that also protected trees deemed to be giants, i.e. determined by a modelled formula, or by detailed measurements, to be 280 m^3 or more in trunk volume.

Cultural heritage values of giant trees

Although exceptionally large and/or tall trees form an important biological and structural part of the wet forest

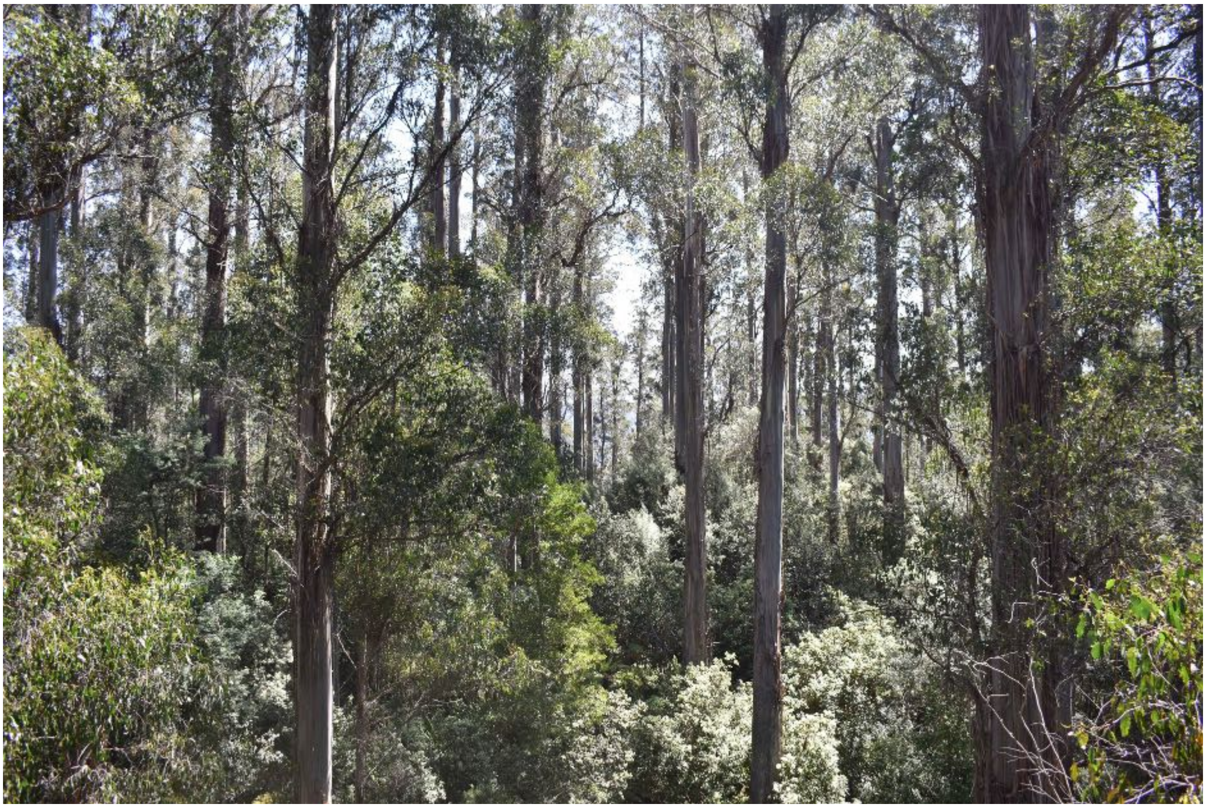

Fig. 13. Example of a maturing stand of *Eucalyptus regnans* in the Manning Reserve, Florentine Valley, Tasmania. This single-aged cohort of 220-year-old trees includes individuals up to 91.5 m tall, even though their maximum volume is small (80 m^3) relative to massive trees in significantly older giant forests (>500 years). (Photo: B. Mifsud.)

and mixed-rainforest environments, the recognition and protection of individual massive or tall trees, or particularly impressive groves within a landscape, falls more under the category of natural heritage than biodiversity. Griffiths (1992) wrote that 'Tall and ancient trees earn recognition not just as members of a species but as individuals. They are visited, studied, named and beloved' (pp. 143–144). However, attitudes towards giant trees have varied over time. In the late 19th century, Nicholas Caire photographed and measured many large specimens of *E. regnans* in Victoria, giving them era-appropriate names such as, 'Big Ben', 'King Edward VII' and 'Uncle Sam'. (Caire 1905). The 'Furmston Tree' also in Victoria, was a popular destination for walkers in the 1930s from the town of Healesville and was promoted on a poster as a tourist site (Griffiths 1992; Anon. 2018). Similarly, in Tasmania, in the late 1890s and early 1900s, giant trees were also given names such as 'Lady Lefroy's Tree' and 'Big Ben' (Kostoglou 2000). However, by the time a giant *E. regnans* tree was found and measured on Mount Nicholls (Helms 1945), there appeared to be no thought of creating a tourist attraction at the site of the living tree itself. Instead, once cut, two sections of the tree's enormous base were moved to New Norfolk and Maydena, where people driving past can still see them today. Similarly, visitors to Tasmania can see giant logs in public parks in Campbell Town and Geeveston. The idea of showing off giant stumps or logs instead of a living tree perhaps indicated a shift away from a focus on appreciating nature, to demonstrating how industry had conquered nature. It is arguably more common for tourists in Tasmania to see a giant stump or log in a township than to experience a living giant in the forest.

To direct resources towards protecting giant trees, it is essential that people are able to experience them. However, the number of fully accessible sites for the public to easily visit impressively large or tall trees via maintained walking tracks is currently limited to the Styx Valley Big Tree reserve, Mount Field National Park (Tall Trees walk), Dip Falls Reserve and the Blue Tier Giant walk near Weldborough. Although these sites have good examples of tall eucalypt forest and some impressive individual trees, none contains any of the 40 tallest or 40 largest measured trees. Compounding the issue of public accessibility to giant trees, the Arve Big Tree, which was the most accessible giant tree in the State, reached by a sealed road and with a raised viewing platform with wheelchair access, collapsed following damage from the 2019 bushfires (Ogilvie 2019). Furthermore, the Evercreech Reserve near Fingal in the north-east of the state, once home to the tallest known *E. viminalis* tree 'Sir Vim', is no longer a viable tall-tree tourist destination following the death of the tallest trees from drought-induced 'ginger tree' disease (Steane 2020). We therefore suggest expanding the number of groves containing giant and tall trees that the public can easily access. Potential sites could include places where previous infrastructure has been neglected or become overgrown, such as at the Lady Binney and Andromeda groves (former ANM sites) and at the Tolkien track (Orford 2004; The Wilderness Society 2020).

While public visitation is essential to build a 'constituency' that will advocate and promote the conservation of giant trees, it is important it is carefully managed to avoid adverse impacts such as trampling and soil compaction, damage to surrounding vegetation to enhance access or views, introduction of pathogens and removal of epiphytes and other damage as a result of unregulated recreational tree climbing. Accordingly, throughout this review we have mostly used field codes rather than the evocative names that many of the giants have been given by the citizen-science giant-tree community. Experience in the USA has shown that unregulated promotion of giant trees, especially on social media, has led to environmental damage requiring government protection through fines (NPR 2022; NPS 2024).

Clearly, a balance needs to be struck between making a few accessible trees available for public enjoyment versus secrecy and regulation of the remaining giants, as was the case for a renowned grove of giant trees in Jedediah Smith Redwoods National Park, USA (NPR 2022). This issue is more problematic, given the increasing need for active management of giant trees to mitigate against the twinned threats of climate change and wildfire that will require increasing levels of localised management, including irrigation, wildland fuel removal, wrapping in protective fireproof material, and targeted fire suppression. Such interventions are already occurring in the USA and increasing in Australia. For instance, extraordinarily rare and significant *Wollemia nobilis* stands in the Blue Mountains were protected from fire using irrigation and airdrops of fire retardant during the 2019–20 bushfire crisis (Nolan *et al*. 2021). The complexity of giant-tree conservation that involves trade-offs between restricting public accessibility, increasing community awareness and active versus passive management argues for a detailed conservation planning and ongoing commitment of human and operational resources that are currently lacking in the Tasmanian Wilderness World Heritage Area Management Plan, despite giant trees being recognised as an outstanding natural value of this region (DPIPWE 2016).

Conclusions

Tasmania has internationally significant trees that combine great size and height. The largest *E. regnans* tree, with a trunk volume of 463 m^3, is the most massive angiosperm known on the planet and is also the largest-trunked tree in the southern hemisphere. Until recently, the tallest *E. regnans* tree, at 99.8 m tall, was the tallest flowering plant in the world. Although it has recently lost almost 4 m in height because of recent bushfire damage, the species still ranks in the top-six tallest living species globally. Unfortunately, Tasmania's largest and tallest trees face multiple threats of advanced age, increased fire frequency and severity, and climate change. Therefore, it is vital to safeguard their ongoing viability in the landscape, not only so they can fulfil their essential role as the keystone species in their wet forest environment, but also to ensure that both current and future generations can experience the grandeur of one of the world's most impressive tree species.

Supplementary material

Supplementary material is available online.

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Data availability. The data that support this study will be shared upon reasonable request to the corresponding author.

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