Eucalypt growth-ring research and tree ages at Warra 17B, southern Tasmania

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Abstract

Fire is an important part of the Australian environment. There has been a lot of interest in mapping fires and trying to understand how they affect the landscape. In this study, we looked at two sites in a small area in the Warra Long-Term Ecological Research site, both in coupe Warra 17B, in order to try to work out when fires last went through the sites. Even though our two sites were very close to one another, the ages of the trees were very different. Based on ring counts from Eucalyptus *spp. and* Phyllocladus aspleniifolius, *there have been a number of fires at one site (the Upper Site) over the past 500-600 years, none of which destroyed all the trees at the site. At the other site (the Lower Site), the eucalypts were of a similar age to each other, suggesting that the most recent fire did destroy all the trees at this site, with eucalypts then starting to grow before* P. aspleniifolius *and* N. cunninghamii. *We also examined the relationship between ring widths of* Phyllocladus aspleniifolius *and local temperature and rainfall. Ring widths seem to be more related to minimum temperature than maximum temperature or rainfall. The relationship with minimum temperature was negative.*

Keywords: *Eucalyptus, Phyllocladus aspleniifolius,* tree rings, fire, climate

Introduction

In Australia, a lot of work has been done on fire and its effects (e.g. Gill 1979; Cheney 1979; Burrows and MacCaw 1990; Kershaw *et al.* 2002; Turner *et al*. 2009, amongst many more). In Tasmania, Marsden-Smedley (1998) mapped the extent of fires in the southwest since the late 1800s, and found that very large fires burnt the area in the 1890s and again in 1934. Johnson and Marsden-Smedley (2002) looked at fire regimes in the northern part of the Cradle Mountain-Lake St. Clair National Park/Walls of Jerusalem National Park and parts of the Central Plateau area by looking at aerial photographs, fire maps and published papers. They found that periods of few and small fires were followed by a large fire. von Platen (2008) examined changes in fire regimes over the past 300 years in eastern Tasmania through ring counts on eucalypt stumps at several sites in the Eastern Tiers. She found five different periods distinguished by their fire frequency. The first period was prior to European arrival in the area (1740-1819) when there were approximately 0.7 fires per decade. Changes in European land management practices after colonisation resulted first in a decrease in the number of fires (to approximately 0.4 per decade, 1820-1849) followed by a transitional period (1840-1850) to a period of more fires (0.8–1.2 per decade, 1850s-1909), then a further sharp increase (1.3–1.7 per decade, 1910-1989), followed by a decrease in most recent times.

Forestry Tasmania has been trying to work out when historical fires have burnt in and around the Warra Long-Term Ecological Research site in southern Tasmania (Figure 1).

Forestry Tasmania has also been interested in researching when standing trees of different species (e.g. eucalypts, celery top pine) established. Even-aged forest stands may be an indication of large-scale stand-replacing fires, whereas multi-aged forest stands suggest smaller-scale fires have occurred during stand development over perhaps several hundred years. Whether forest stands are multi-aged or even-aged has important implications for forest management (Hickey *et al*. 1999). Hickey *et al.* (1999) examined fire frequency at Warra by looking at aerial photographs, and performing ring counts on understorey species. They found that the eucalypt forests of the Warra area established after various fires between 1500 and 1850. Further to this work, Alcorn *et al*. (2001) used ring counts to establish that there were multiple cohorts of *Eucalyptus obliqua* trees present in the Warra LTER. They estimated that there were six cohorts of old trees, and that these had established between 1500 and 1900.

In North America, there have been many studies of fire by dendrochronologists. These studies usually used long-lived trees with annual rings that kept growing after the fires happened, and with fire scars to mark the date of the fire (e.g. Grissino-Mayer *et al.* 2004; Swetnam *et al.* 2009). If Tasmanian eucalypts produce annual rings, then it should be possible to use standard dendrochronological approaches to develop cross-dated fire history chronologies from some species in fire-prone areas. Cross-dating (Stokes and Smiley 1968) is considered the corner-stone of dendrochronological work. Simple ring counts may, however, provide reasonable approximations for the timing of certain events (S. Wood, University of Tasmania, pers. comm.) and may be useful for ecological studies. Many researchers, including Forestry Tasmania, rely on eucalypt ring counts for dating trees. This was the case for *E. pauciflora* and *E. stellulata* (Morrow and La Marche 1978). Brookhouse (2008) also looked at rings in *Eucalyptus* spp. in the Snowy Mountains

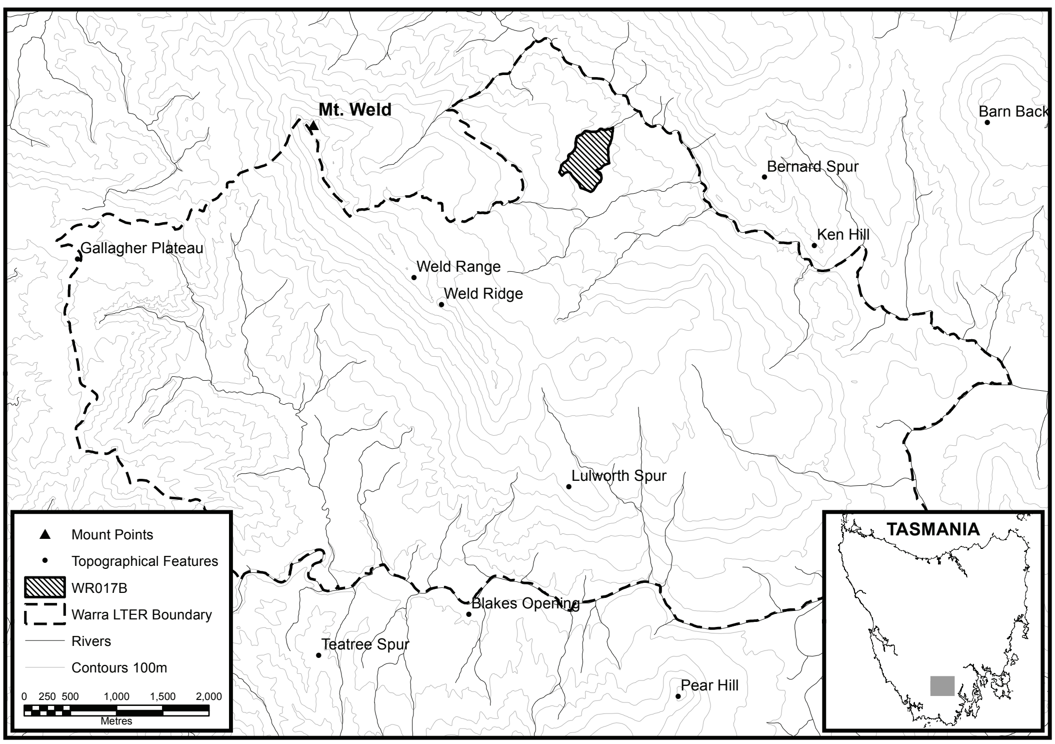

Figure 1. Location of coupe WR017B in the Warra Long-Term Ecological Research site.

area, and concluded they were annual. von Platen (2008) was not able to cross-date her samples, but nevertheless derived decadal-scale information about changes in fire frequency.

In Tasmania, we have several long-lived trees such as *Lagarostrobos franklinii* (Huon pine), *Athrotaxis* spp. (King Billy pine, pencil pine), *Phyllocladus aspleniifolius* (celery-top pine) and *Nothofagus cunninghamii* (myrtle). The first three of these are known to have annual rings, and it is probable that *N. cunninghamii* also has annual rings. Huon pine data have been used to reconstruct temperature (Buckley *et al.* 1997) and sea-surface temperatures (Cook *et al*. 2000). The climate response of celery-top pine has also been examined in an attempt to determine its usefulness for climate reconstruction (Allen 1998). Some work has also been conducted on King Billy pine and pencil pine (Ogden 1978; Allen *et al*. 2011). However, these species are usually killed by fire, so very few studies of fire cycles using these species have been done. On the other hand, many species of *Eucalyptus* need fire to regenerate, but will only be killed by severe fires.

We wanted to see if it was likely that *E. obliqua* trees in the Warra LTER produce one ring per year like celery-top pine, if they were likely to produce approximately one ring per year, or if ring counts were likely to be very unreliable. We also wanted to define the age of celery-top pine in two adjacent sites at Warra, to see if the eucalypts were or were not about the same age as each other and the celery-top pine, and to find out about fires that went through those sites. Because we are trying to see whether all the trees at a site were about the same age and therefore whether a stand-wide disturbance, such as fire, was responsible for their establishment, this research is of interest to forest ecologists.

Our specific aims were phrased in relation to the two study sites we identified at Warra:

- to see if the eucalypts were about the same age as the celery-top pine at the Upper Site, and if the eucalypts had approximately one ring per year.
- to check ring counts on the *E. obliqua* stumps at the Upper Site to see if they were around the same age as one another, and therefore if they came up at the same time due to a single fire.
- to use ring counts to see whether the ages of the trees at the Lower Site are consistent with fire occurring at that site in 1934.

An important assumption of our project was the assumption that all trees originally established after a fire or fires. This assumption has been widely used by researchers relying on different cohorts of trees to deduce fire events.

Methods

The sites

We conducted research on eucalypts and rainforest species at coupe Warra 17B (Figure 1), which is in State forest and part of the Warra Long-Term Ecological Research site. The Warra LTER was established for research on the ecology of wet eucalypt forests. Warra 17B was part of a special trial and had been logged in patches between July 2000 and September 2004 for non-commercial purposes (Peter Pepper, Forestry Tasmania, pers. comm.).

We looked at two logged sites within Warra 17B, one up-slope (the Upper Site) and one down-slope (the Lower Site). We sampled the sites in 2007. Both sites had stumps of *E. obliqua* (although it is possible that some of the *E. obliqua* trees contained genetic material from *E. delegatensis*: M. Neyland, Forestry Tasmania, pers. comm.). The Lower Site had more *E. obliqua* stumps and these were smaller (50-70 cm in diameter). It was believed that a fire passed through the Lower Site in 1934 (S. Davis, Forestry Tasmania, pers. comm). The Upper Site had fewer *E. obliqua* stumps but they were significantly larger (in excess of 1.5 m in diameter). The unlogged vegetation near the Lower Site also appeared much younger than the unlogged vegetation near the Upper Site. There were several other special timber species present at both sites, such as celery-top pine (*Phyllocladus aspleniifolius*), blackwood (*Acacia melanoxylon*), myrtle (*Nothofagus cunninghamii*) and silver wattle (*Acacia dealbata*).

Upper Site

At the Upper Site, we selected eight *E. obliqua* stumps based on the visibility of their rings, the amount of rot in their centres, and their circularity. For each selected stump, the lengths of two radii were measured from the outside edge to the estimated pith (middle). The surfaces of the selected radii were planed with a hand planer to improve visibility of the rings. For the *E. obliqua* stumps that were not solid in the centre, an estimate was made as to where the pith would be. For these rotten *E. obliqua* stumps, the distance between the estimated pith position and the solid wood was also measured. All visible rings were counted along the two radii by two different people in our group. This method is similar to that used by von Platen (2008).

For *E. obliqua* stumps that had a rotten centre, we had to estimate the number of missing rings in order to get an estimate of how old the tree was. We first measured the distance from the outside edge where the wood was solid, to the inside edge where the wood was rotten, then counted the number of rings on this solid segment of wood. We calculated the average ring width by dividing the width of the solid wood by its number of rings to give the average ring width. We then worked out how many of these average ring widths would fit into the rotten gap to the estimated pith position, and added this number to the number of rings counted for the solid segment, to get an estimated total number of rings for each stump.

We selected one large celery-top pine stump at the Upper Site and cut a disc off the top, with the help of Forestry Tasmania. We took this disc back to Geeveston District High School and sanded it using sandpaper up to 400 grit. This made seeing the rings significantly easier. We then counted the rings and, with a pin, put one pin-prick mark every decade, two for every fifty years, three for every century and four for every millennium. We did not have magnification so it is possible that we missed some rings in patches where the rings were very narrow. Therefore our count provides a minimum age of the tree.

Lower Site

We selected eleven eucalypt samples and one blackwood sample for disc ring counts from the Lower Site, in an attempt to identify when the trees established and therefore approximately when a fire last burnt the site. Forestry Tasmania again helped us cut the discs. We selected the trees on the basis of how concentric their rings were, because this made it easier to count the rings along two radii. Although there were many *E. obliqua* stumps at the Lower Site, most were not suitable for ring-counting. The reason for this was that the centre ring was not physically near the middle of the *E. obliqua* stump, making it difficult for us to count the rings along two radii of the sample. We needed to count the rings on two radii to check whether there were the same number of rings along each, and were therefore limited to 11 eucalypt samples from this site.

We cored seven trees (two myrtle and five celery-top pines) near the Lower Site. Some of these cored trees were used for ring counting, while others were used for measuring ring width. We only measured cores for two celery-top pine trees and one myrtle tree.

When we took the samples back to the school, we sanded them in the same manner as the celery-top pine form the Upper Site. We then counted the rings on the eucalypts and the blackwood. All visible rings were counted along two radii (the rings on each radius were counted by two different people in our group) and we took an average of the two ring counts for each sample. We used the two radii and counts by two people to try to minimise errors in the counts we made.

We used an image-analysis program (WinDendro) to measure the rings on the core samples of myrtle and celery-top pine from the Lower Site, and created graphs of ring widths in Microsoft Excel. We also made numerical comparisons of ring-width series from pairs of measured celery-top pine samples using Pearson's correlation coefficient.

Climate data

We used climate data from stations around Geeveston to try to determine whether there was a relationship between climate data and ring widths. The precipitation stations initially chosen were 94137 (Geeveston, Cemetery Rd), 94116 (Geeveston, Riawunna), 97065 (Tahune), 94146 (Geeveston, Fourfoot Rd) and 97024 (Warra). The data came from the Bureau of Meteorology. Although the amount of precipitation at the stations differed, the patterns of annual precipitation were similar (Figure 2). To compare the pattern of ring widths with the pattern of rainfall, we used only the Geeveston, Riawunna (94116) precipitation record, because this station had one of the longest records. We also used annual temperature data from Geeveston, Cemetery Road (94137) for each month from 1987 to 2007, as this was the only station in the area that had recorded temperature for more than 10 years. There were some missing data for some months, and for these we used the average rainfall or temperature for that month when we calculated the annual total rainfall or annual average maximum or minimum temperature. The climate data were compared with the ring widths of two celery-top pines from 1965, to see, for example, if periods of cold temperature or low rainfall coincided with smaller ring widths. We calculated Pearson correlation coefficients between each of the climate variables and average ring width series.

Results

Ring counts at the Upper Site

The estimated number of rings in eight eucalypts at the Upper Site varied from 250 to 557 (Table 1). This compared with the single celery-top pine ring count of just fewer than 600. The celery-top pine thus dated back to

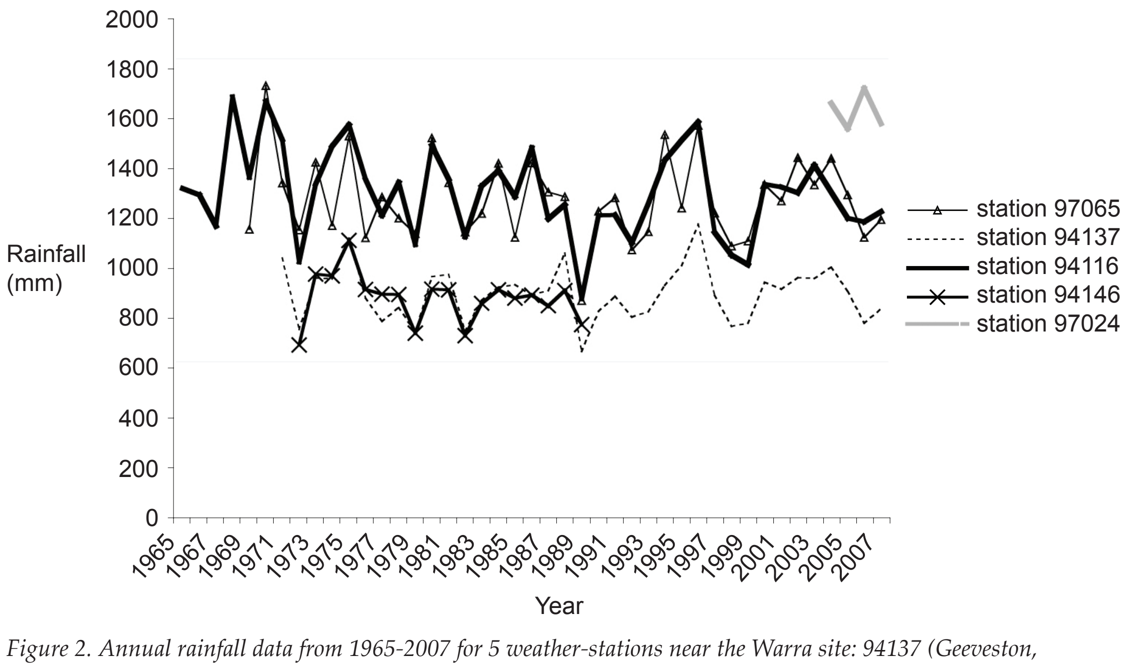

Figure 2. Annual rainfall data from 1965-2007 for 5 weather-stations near the Warra site: 94137 (Geeveston, Cemetery Rd), 94116 (Geeveston, Riawunna), 97065 (Tahune), 94146 (Geeveston, Fourfoot Rd) and 97024 (Warra).

Year

Table 1.Eucalypt and celery-top pine ring counts from the Upper Site. Euc6 did not have any rot in its centre. The "Centre to outer edge" distance is the average distance along 2 radii from the estimated centre of the tree to its outer edge, that is, to the outermost ring. The "Centre to innermost ring" distance is the average distance along 2 radii from the estimated centre of the tree to the innermost measurable ring, representing the amount of wood and rings lost due to rot. The difference between these measurements represents the amount of wood with measurable rings. For the celery-top pine, there were some very tight sections in which we may have missed some rings.

Sample	Centre to outer edge (cm)	Centre to innermost ring (cm)	Measurable wood	Ring count	Average ring width (cm)	Calculated number of missing rings	Estimated total number of rings
EucU1	84	7.5	76.5	360	0.213	35.3	395.3
EucU2	153	50	103	280	0.368	135.9	415.9
EucU3	132	44	88	300	0.293	150.0	450.0
EucU4	110	15	95	420	0.226	66.3	486.3
EucU5	124	12	112	445	0.252	47.7	492.7
EucU6				250			250.0
EucU7	160	60	100	348	0.287	208.8	556.8
EucU8	84	20	64	250	0.256	78.1	328.1
Celery-top pine				590			

around AD 1400, and probably established between 1350 and 1400.

Ring widths and counts at the Lower Site

Table 2 shows the average ring count for trees of several species measured at the Lower Site. Most of the eucalypt samples contained around 60-75 rings (average 70.8 rings, $\sigma = 7.4$). The celery-top pines at this site had fewer rings than the eucalypts (average 51.5 rings, $\sigma = 7.5$), with these values being significantly different (two sample t-test, $p = 0.008$). The t-test result suggested that the eucalypts began to grow first, assuming they grow at a rate of approximately one ring per year. It should be noted, however, that the t-test was performed with very low sample numbers and uneven groups. The myrtle had 53 rings.

Figure 3 shows the pattern of tree ring widths from two of the celery-top pine samples that we cored at the Lower Site. The rings in the other three celery-top pine samples were very difficult to measure at some points along their radii, so we have not shown these in the Figure. We have, however, noted the ring counts from these samples (Table 2). It was also very difficult to see the rings in the myrtle that was cored, so we have not shown this either. For one myrtle sample it was so difficult to identify rings, that we have not used the ring counts for that tree in this study.

The trend in celery-top pine ring widths differed between trees. For Tree 4, there was more rapid growth in the early (first 20) years of its growth. Growth slowed down after that time but then peaked around 2004. The downward trend in the growth of Tree 1 was much less pronounced than for Tree 4; the year of its lowest growth was 2003 (Figure 3). Table 3 shows the correlation coefficients of ring widths for the four radii measured across the two celery-top pine cores shown in Figure 3. For celery-top pine 4, the correlation coefficient between the ring widths of its two measured radii was strong (0.918), but most of the other correlations were poor.

Celery-top pine ring widths and climate data

Over the period that the celery-top pines at the Lower Site have been growing, rainfall has varied around an average of about

Table 2. Ring counts of eucalypts and other species at the Lower Site. Each ring count is the average of 2 counted radii. The eucalypt and blackwood rings were measured on discs cut from stumps, and the celery-top pine and myrtle rings were measured on tree cores. It was not possible to count rings in the second cored myrtle (not included in Table).

Sample	Average ring count
EucL1	66
EucL2	73
EucL3	69
EucL4	59
EucL5	75
EucL6	75
EucL7	40 (not to middle)
EucL8	85
EucL9	75
EucL10	68
EucL11	63
Myrtle1	53
Celery1	46
Celery2	63
Celery3	47
Celery4	46
Celery5	55
Blackwood	64

1200 mm (Figure 3). The data also show that, when there was a peak in the rainfall, there was also a peak in ring widths (Figure 3). However, the dips in the rainfall record do not always coincide with the dips in the ring width records. The Pearson correlation between rainfall and the averaged rings widths of celery-top pine Tree 4 was 0.26, while the Pearson correlation between the averaged ring widths of Tree 1 and rainfall was 0.02.

The pattern of maximum temperature variation is not the same as the pattern of ring widths (Figure 4). At the end of the temperature record, growth in Tree 4 decreased at the same time as maximum temperature increased. The Pearson correlation between maximum temperature and averaged ring widths of Tree 1 is -0.32, and between the averaged ring widths of Tree 4 and maximum temperature is -0.01. Ring widths and minimum temperatures are also negatively correlated (Figure 5). The Pearson correlation between the averaged ring widths of Tree 1 and minimum temperature was -0.46, and that between the averaged ring widths of Tree 4 and minimum

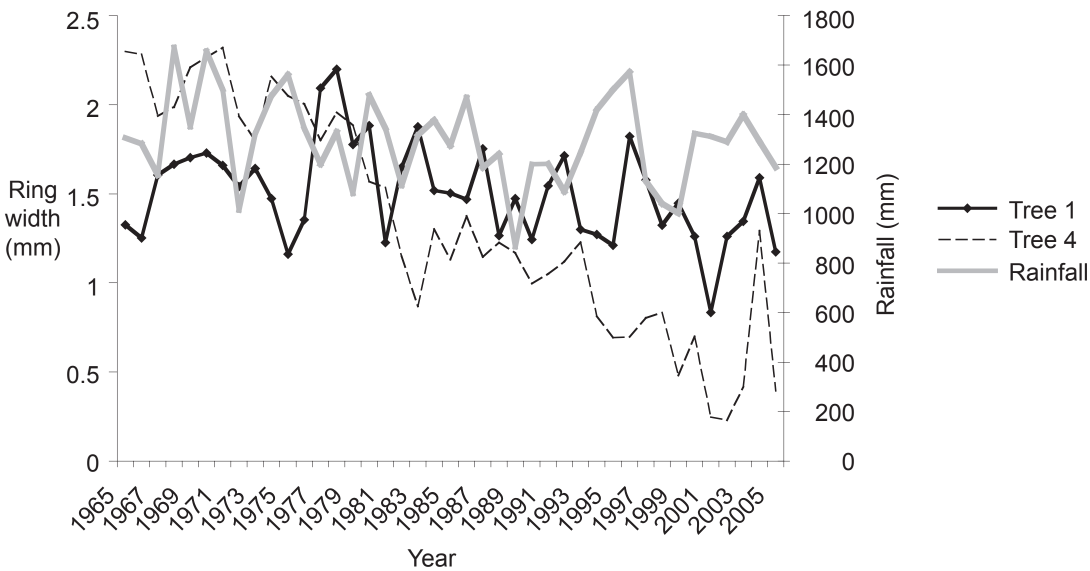

Figure 3: Ring widths from two celery-top pine trees (Lower Site), and rainfall at station 94116 (Geeveston, Riawunna). Station 94116 was chosen because it had the most complete and longest rainfall record.

Table 3. Correlation coefficients for ring widths of celery-top pine samples from Trees 1 and 4. 1a and 1b represent different radii from Tree 1, and 4a and 4b represent different radii from Tree 4.

	1a	1b	4b	4a
1a	1	0.343	0.238	0.155
1b		1	0.065	0.142
4b			1	0.918
4a				1

temperature was -0.47. These are relatively strong correlations and were stronger than for any other climate variable. Of all the correlations between climate and ring widths, the correlations between ring width and minimum temperature are the only ones that are statistically significant ($p \leq 0.05$). As ring widths declined over the last ten years (most noticeably for Tree 4), minimum temperature was steadily going up, but this decrease in growth may be related to climate or to a trend in tree ring width that can occur as a tree ages. The rise in minimum temperatures for Geeveston is consistent with other minimum temperatures around Australia, which have also been steadily rising.

Discussion

Were the eucalypt rings annual?

At times it was difficult to identify individual rings on the eucalypt trees at the Upper Site due to the fact that most of the trees were quite old. This made it harder to count the outer rings because they were very small. It is certainly possible that we missed some rings when counting. We estimated that the celery-top pine at the Upper Site started growing about 600 years ago. If the oldest eucalypt started growing at the same time as the celery-top pine, then we can estimate that eucalypt had about 50-100 'missing' rings, or that it grew less than one ring per year. However, previous observations (by K. Allen) of a number of samples from several species of eucalypts suggest that eucalypts are more likely to have false rings than missing rings. Any 'missing' rings are more likely to have been rings that we missed counting in the outer portions of the stumps, than rings that did not form.

The ability to cross-date between trees fulfils a necessary, but not sufficient, condition for rings being annual (see http://web.utk.edu/~grissino/principles.htm). We did not cross-date the eucalypts with other trees because it was beyond the scope of this study. Approximately the first hundred years of *E. regnans* growth cross-date for a site in the Styx Valley, Southern Tasmania (S. Wood, University of Tasmania, pers. comm.), but von Platen (2008) had a lot of trouble trying to cross-date other eucalypt species from eastern Tasmania, including *E. obliqua*. Young (30-40 year-old) *E. pulchella* have however shown evidence of weak cross-dating (von Platen and Allen, unpubl. data.). Based on what we did in this study, we could not tell whether the eucalypt rings were annual or not because we did not try to cross-date them. Based on previous research by others and the reasonable consistency in ring counts between *E. obliqua* stumps at the Lower Site, we concluded that the eucalypt rings were approximately annual.

Estimated tree ages at the Upper Site

Because eucalypts are more likely to have false rings than missing rings, we should ask whether one event was responsible for the establishment of the celery-top pine tree and another for the establishment of the eucalypts at the Upper Site. It is possible that we did not sample *E. obliqua* stumps that established at the same time as the celery-top pine because we only sampled eight trees and may

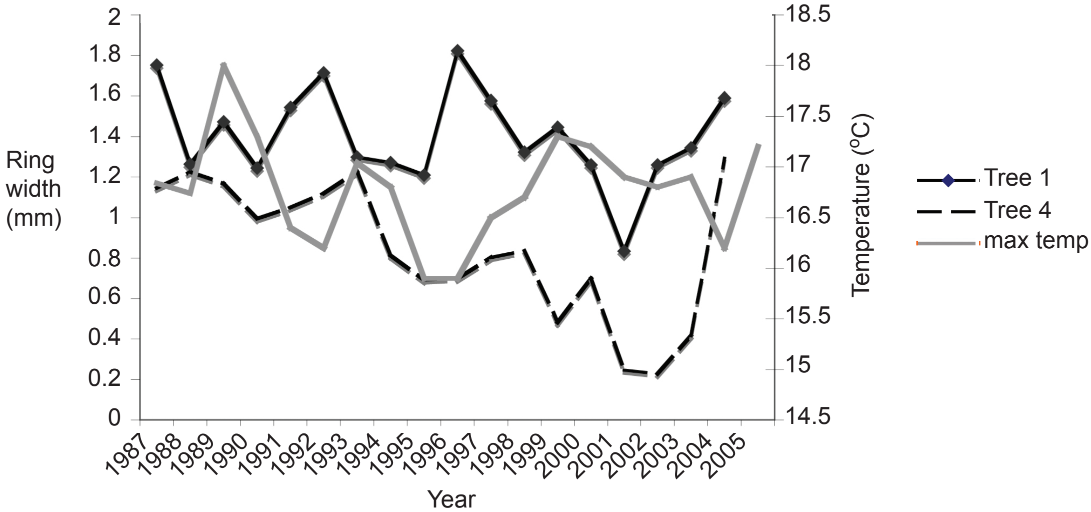

Figure 4. Ring widths from two celery-top pine trees (Lower Site), and maximum temperature at station 94137 (Geeveston, Cemetery Road).

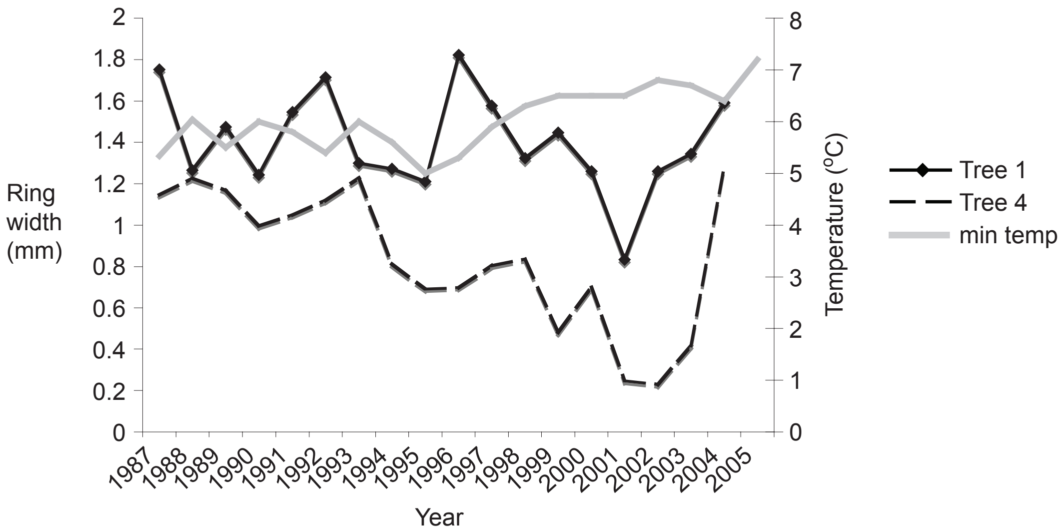

Figure 5. Ring widths from two celery-top pine trees (Lower Site), and minimum temperature at station 94137 (Geeveston, Cemetery Rd).

have missed the oldest trees in the coupe. We may also have missed the oldest trees because their centres were very rotten.

Our oldest eucalypt at the Upper Site started growing about 550 years ago (assuming approximately annual rings), followed by another group that began growing just under 500 years ago, and others that were younger. We also acknowledge that it takes time for the trees to reach the height at which we counted rings, so our estimations could be out by up to 3 decades (but possibly much less). If these numbers are reasonably accurate, the data are consistent with there having been at least four fires in the Upper Site since about 1350-1400 when the celery-top pine tree established. At least three of these fires did not burn the whole stand. There are, however, several uncertainties with the ring counts. First, we have had to estimate the number the rings likely in the rotten centres of several of the *E. obliqua* stumps using average growth rates. These calculated growth rates are possibly over-estimates because, if the trees started growing in open conditions, it is likely that the earliest rings would have been relatively wide compared to later rings. In addition, we have made a rough estimate of the time taken by the tree to reach the height at which we counted the rings. Thirdly, we have assumed that the trees started growing immediately after fires at the site.

Despite these uncertainties, our ring counts suggesting multiple cohorts of trees at the Upper Site are consistent with a number of previous studies. Turner et al. (2009) investigated many stands of *E. obliqua* and *E. regnans* in Tasmania and found that most stands with some trees older than 110 years had trees of different ages in them. Hickey *et al.* (1999) and Alcorn *et al*. (2001) reached similar conclusions for the forests of the Warra area generally. Hickey *et al.* (1999) and Alcorn *et al.* (2001) and Turner *et al.* (2009) have all stated that stand-replacing fires were less common than previously thought, and non-stand-replacing fires more common. The significance of these findings is related to a theory that eucalypts need fire to regenerate and will establish and grow before other wet forest or rainforest species (Jackson 1968). The results of our study do suggest that not all the eucalypts were burnt in a single fire, because it seems some of them are up to 300 years older than others. Although the results are consistent with multi-aged, rather than single-aged stands, it is unclear whether or not they conflict with Jackson's (1968) theory. It is plausible that a number of fires burned different parts of the site at different times. In addition, the fact that the celery-top pine tree at the Upper Site was at least 600 years old, and we think the eucalypts rings were approximately annual, means that this celery-top pine tree established before some of the eucalypts. This in turn suggests that gap-phase regeneration caused by fires that only burn part of the forest stand plays an important role in forest dynamics.

Was there a stand-replacing fire at the Lower Site in 1934?

The average ring count for the eucalypts at the Lower Site (70.8 years, measured in 2007) is consistent with these trees having started growing just after a fire in 1934, if the rings in the samples are approximately, but not exactly, annual. If the trees did start growing immediately after an event in 1934, there must be some false rings in several of the samples. It is also possible that a 1934 fire did not burn all the trees at the site, or that the trees established after other events that may have occurred between about 1920 and 1940. With regard to the celery-top pines we sampled at the Lower Site (average age 51.5 years), Tyquin (2005) has suggested that it would take a celery-top pine about 30 years to grow to 1 m in height. These celery-top pines were relatively fast growing so we think they probably reached coring height (about 1 m) in less than 30 years. If correct, this would suggest they established just after the eucalypts established at the site. It is possible this was the case for the myrtle and the blackwood also. Although our results do not prove there was fire at the Lower Site in 1934, they are consistent with the site having been burnt in 1934.

Based on our measurements of samples from the two celery-top pine trees and the weak relationship between the cores in Tree 1, we think there could have been a missing ring in one of the Tree 1 samples or that we made a mistake when measuring. A chronology built from many trees would have helped us identify whether celery-top pine Tree 1 was misdated. As mentioned before, the development of cross-dated chronologies was beyond the scope of our study.

Climate relationships with ring widths

The relationships between ring widths and maximum temperature, and ring widths and precipitation were generally weak, and also differed between trees. There was a relatively strong negative relationship with minimum temperature, however, with one tree in particular (Tree 4) growing more slowly as temperature rose. It is also interesting to note that, when precipitation was higher, ring widths were also wider. Allen (2002) found a reasonably strong relationship with minimum temperature for a site at 900 m altitude, and reasonably strong relationships between maximum and minimum temperatures and ring widths for other sites in Tasmania, but with a method for investigating relationships that involved building chronologies from many trees.

Conclusion

Based on our evidence, we believe that the ring counts from the eucalypts were approximately one ring per year. It is not possible to state this categorically because it was beyond the scope of our study to try 'industry-standard' cross-dating used by dendrochronologists. If the eucalypts have approximately one ring per year, then none of those at the Upper Site were the same age as the celery-top pine at that site. The celery-top pine tree had the most rings, and we know that rings are annual in celery-top pine. This particular celery-top pine had 600 rings whereas the different groups of eucalypts were all younger. If our assumption that the trees established after a fire is correct, then our ring counts indicate that several fires have passed through the site but missed some of the trees each time. This suggests that stand-wide regeneration after a single major fire was not the case.

The fact that we only examined eight eucalypt samples and one celery-top pine sample from the Upper Site had an impact on our studies, as it gave us less samples to work with. If we had been able to get more samples we could have developed a more accurate approximation of how many different cohorts of trees were present at the site, and possibly a better estimation of how many fires had burnt through the site in the last 600 years.

In contrast to the Upper Site, we have reason think that the trees at the Lower Site regenerated after a single fire event in 1934. Our results led us to think that the eucalypts came up at least a decade before the celery-top pines. The evidence suggests most of the eucalypts regrew reasonably quickly after the proposed fire in 1934, and have few false rings. Others may have started growing a few years after the event. The other species at the site probably came up a few years after the fire event and after the eucalypts started growing. The evidence, again while not conclusive, is consistent with a fire having burnt the Lower Site in 1934.

It would be interesting to investigate relationships between the climate data, and compare these to ring widths over a longer period of time.

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