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ORIGINAL ARTICLE

A 1700-year *Athrotaxis selaginoides* tree-ring width chronology from southeastern Australia

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ABSTRACT

Few Southern Hemisphere tree-ring chronologies exceed 1000 years in length. We present a ca. 1700 years of indexed values for the long-lived conifer *Athrotaxis selaginoides* at Cradle Mt in southeastern Australia and compare it with the only other published millennial-plus length tree-ring chronology for Australia: the nearby Mt Read *Lagarostrobos franklinii*. We use simple correlation function and pointer year analyses to compare the climate responses of the two species (temperature, precipitation and growing degree days). Both chronologies show accelerated growth at their modern ends, but this growth acceleration is not synchronous, beginning approximately a quarter of a century earlier at the Cradle Mt site. This discrepancy may highlight the relevance of chronology composition and/or physiological differences in the species. Although the seasonality of the climatic responses of the two species is similar, that of *A. selaginoides* is generally weaker than that of *L. franklinii*. Somewhat paradoxically, the only pointer years in common between the chronologies are 1898 and 1908 CE. The periods from 600 to 900 CE and ~1200–1450 CE are conspicuous for their absence of positive pointer years while no negative pointer years occur for either site from ~1200–1350 CE. It is possible that differing patterns of pointer years can be partially explained by a peak in establishment from ~1150–1850 CE at the Mt Read *L. franklinii* site compared to continuous establishment at Cradle Mt. Although statistically significant and time-stable climate responses for the *A. selaginoides* chronology are too weak to base a single-chronology climate reconstruction on, the long chronology will likely make an important contribution to future multi-proxy temperature reconstructions for southeastern Australia.

1. Introduction

Paleoclimate records provide a long-term context for recent climatic changes. Tree rings in particular provide annually resolved, multi-centennial to multi-millennial records of climate (temperature and/or precipitation) for many regions of the world (e.g., Ferguson, 1968; Lara and Villalba, 1993; D'Arrigo et al., 2001; Hantemirov and Shiyatov, 2002; Grudd et al., 2002; Buckley et al., 2010; Linderholm et al., 2010). Currently, very few climate-sensitive multimillennial tree-ring chronologies from the Southern Hemisphere have been published, especially from Australasia. In New Zealand, very long records from *Agathis australis* (kauri) have been developed (Boswijk et al., 2014) but so far only the "recent" period of the last 500-years has been used to reconstruct ENSO-variability (Fowler et al., 2012). *Lagarostrobos colensoii* (Silver Pine) provides a record of mean temperature over the past ca. 1200 years (Cook et al., 2002). In Australia, the Mt Read *Lagarostrobos franklinii* chronology is the only published temperature-sensitive chronology that exceeds 1200 years (Cook et al., 2000, 2006). Although each of these Australasian records has facilitated critical insights into past climate, increasing the number of such long climate-sensitive Australasian tree-ring chronologies will greatly improve the robustness of regional climate reconstructions (Jones et al., 2009a).

In this paper we present a ca. 1700-year *Athrotaxis selaginoides* chronology derived from living and dead trees from the Cradle Mountain-Lake St Clair National Park, Tasmania. We compare it with the nearby *L. franklinii* Lake Johnston site at Mt Read that is situated at a comparable elevation to Cradle Mountain. Because temporally stable climate responses are critical for high-quality reconstructions and have been a noted concern (e.g. D'Arrigo et al., 2008), we interrogated the temporal stability of statistically significant relationships between the

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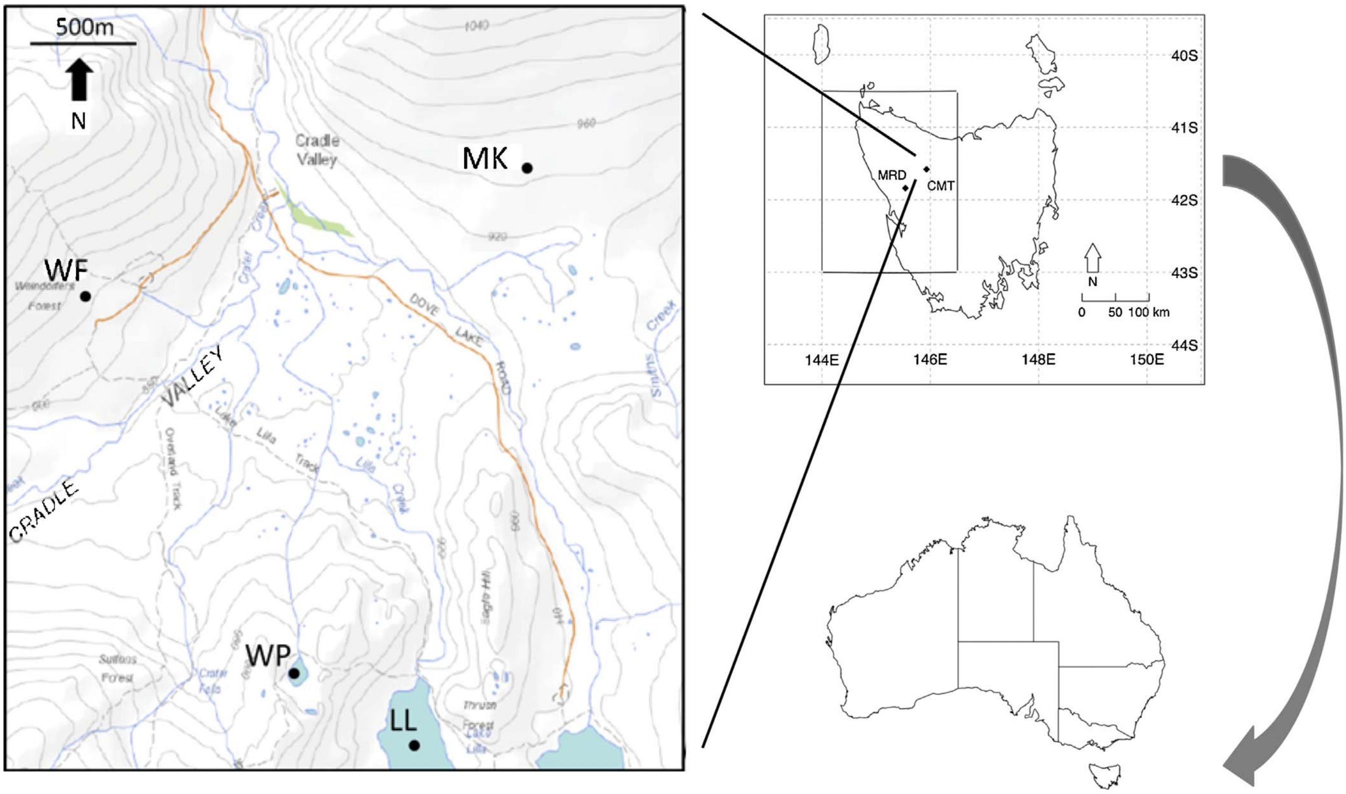

Fig. 1. Location of millennial-plus length chronologies at Cradle Mt (*A. selaginoides*) and Mt Read (*L. franklinii*). The finer scale site map shows site location, from Weindorfer's Forest (WF) across to Mt Kate (MK) and the location of charcoal records at Wombat Pool (WP) and Lake Lilla (LL). The box over the map of Tasmania indicates the area from which climate data (AWAP) were averaged. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

chronologies and identified multi-month climate windows. By examining the strength and temporal stability of the chronology's relationship with climate, we assess the potential for the very long *A. selaginoides* chronology to be used in climate reconstruction. Since each chronology contains 200+ samples, an examination of chronology composition was also undertaken to see if there are any clear patterns that may be related to cohort establishment or major environmental disturbances.

2. Materials and methods

2.1. The Cradle Mt site

Our study site is located in the central northwest of the Australian island state of Tasmania (Fig. 1). The site is located at the northern end of the Cradle Mt – Lake St Clair National Park and has a southerly aspect. The area extends from Weindorfer's Forest (WF) across to the adjacent lower slope of Mt Kate (MK; Fig. 1) and ranges from ~900 to 960 m ASL. At the foot of both slopes is an open expanse of *Gymnoschoenus sphaerocephalus* (buttongrass) while above the site, the vegetation grades to shrubby heathland. There is evidence of past fire disturbance above the site, with many living trees along the forest's edge bearing large fire scars. The date of this relatively low intensity fire (high intensity fires kill the species) is currently unknown, although Kirkpatrick and Balmer (1991) note that it occurred prior to 1890 CE. Approximately 50 km to the west along western Tasmania's coastal range is the ~900 m ASL Mt Read site where records of the endemic Huon pine (*Lagarostrobos franklinii*) were used to develop a four millennia reconstruction of warm season (November–April) temperature (Cook et al., 1991; 1992, 2000, 2006) that has recently been updated (Allen et al., 2014).

2.2. Sample collection and processing

For this study we used tree cores of living and dead *A. selaginoides* that were collected at three different times over the past three decades. The site was first sampled by LaMarche et al. in 1976 (LaMarche et al., 1979), and then by co-authors Cook and Buckley in 1990. The site was sampled for a third time over two years (2008 and 2009) by Allen, Fenwick and Palmer. Although the most recent sampling obviously enabled the chronology to be updated to 2008, the main focus was to extend the chronology further into the past than the previously published version (Allen et al., 2011; ie from 999 CE to 2008 CE). In this latest collection, we cored 77 dead trees and logs and 22 living trees at the site. Each tree or log was cored 3 times.

All newly collected Cradle Mt core samples were air dried, mounted and sanded until the cellular detail became visible. The growth rings from within and between trees were visually crossdated against one another followed by comparison with previously dated trees from the Allen et al. (2011) study. We then measured all individual growth rings and tested the accuracy of our crossdating by comparing our measured ring width time series using the quality control program COFECHA (Holmes, 1994).

For dendroclimatological studies, tree-ring time series are standardised to remove non-climatic variance in the ring-width series. For this purpose we used an age-dependent smoothing spline whose flexibility decreased with increasing tree age (Melvin et al., 2007) and we applied this detrending within the signal-free framework described by Melvin and Briffa (2008). A climate-related common forcing signal in the tree-ring data can bias the fitting of growth curves used to remove non-climatic variance and may lead to a loss of medium frequency signals that are actually attributable to climate. Signal-free standardisation better preserves the common medium-frequency variation that is related to climate compared with non-signal-free methods. This method also eliminates trend distortion effects caused by that same common