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Exploring the relationship between Aboriginal population indices and fire in Australia over the last 20,000 years

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ABSTRACT

The extent of prehistoric human impact on the environment is a contentious topic in various palaeoenvironmental sciences. The long history of humans in Australia and its extensive fire-prone biota makes this continent a key research area for better characterization of prehistoric human–fire interactions. Here we use statistically robust cross-correlation of archaeological radiocarbon data (n = 4102 ages from 1616 sites) and a new synthesis of charcoal records (n = 155 sites) to test for any relationship between people and fire over the last 20,000 years at continental and regional (25–45°S) scales. We find that the statistical correlation between the two datasets is weak at both spatial scales, with short-lived synchronous responses only in the terminal Pleistocene–Holocene transition, at the onset of the mid-Holocene climatic optimum (~10–7 ka) and during significant transitions of El Niño Southern Oscillation (~5–4 ka and 1.2–0.8 ka). One interpretation of this is that Aboriginal populations were implementing 'fire-stick farming' only intermittently during periods of societal stress resulting from climatic variability. However, the synchronicity of the correlations with climate changes, along with the low populations through much of this time, suggests that both datasets were independently responding to external climatic forcing. Under either scenario, a lack of significant change in the charcoal record implies that there were no long-lasting impacts to the environmental biota, and macro-scale palaeoenvironmental records prior to European colonization largely reflect responses to non-human influences. While we do not discount the possibility of systematic or deliberate manipulation of fire regimes at local spatial scales, we conclude that human control of fire by prehistoric people in Australia is not evident at broad landscape levels. This conclusion contradicts persistent suggestions of Australian-wide land management and the pervasiveness of the impacts of 'fire-stick farming'.

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1. Introduction

The systematic modification of the landscape by Aboriginal people using fire was first proposed as a concept in the 19th Century (Curr, 1886), but it was not until Tindale (1959), and especially Jones (1969) who coined the term 'fire-stick farming', that it became a focus for archaeological and Quaternary palaeoenvironmental research. Jones (1969) suggested that fire was an integral part of the Australian prehistoric economy and this led to the widespread modification of biota. His hypothesis led to considerable debate, and there is still little agreement on the extent to which Aboriginal people were land managers (e.g. Hallam, 1975; Bliege-Bird et al., 2008, 2013), or how much observed ecological changes over the last 50,000 years should be attributed to them (e.g. Horton, 1982; Kershaw, 1986; Benson and Redpath, 1997; Bowman, 1998; Miller et al., 2005; Mooney et al., 2011; Notaro et al., 2011; Bird et al., 2013; Sakaguchi et al., 2013). These issues have extended into political and conservation management literature, and similarly remain contentious (e.g. Bowman, 1998).

Despite the debate, significant relevant advances have been made in the last decade, with analysis of contemporary Aboriginal community practices and satellite imagery of post-contact landscapes providing clear evidence of anthropogenic burning (e.g. Burrows et al., 2006; Bliege-Bird et al., 2008, 2013; Bowman et al., 2008; Bird et al., 2009; Smith, 2013). These human behavioural and ecological studies show that fire was used for a range of activities, including for hunting, 'cleaning up country', protection of religious sites and stands of fire-sensitive trees, and asserting ownership of land (Smith, 2013). An incidental consequence of these practices was an enhancement of short-term productivity, increasing patch diversity, reduction in the risk of wildfires through more regular and frequent small-scale burning, and an increased mosaic of small patches of vegetation at different successional stages across the landscape (e.g. Bliege-Bird et al., 2013).

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Bliege-Bird et al. (2008) hypothesized that these behaviours become increasingly important only in the mid–late Holocene as larger, more closer settled, populations inhibited mobility, and forced a broadening of diet to include lower calorific resources (see also Burrows et al., 2006; Bird et al., 2009; Williams et al., in press); they further suggested that populations would not have been sedentary or dense enough to have developed this practice in the late Pleistocene — a finding more recently re-iterated by Williams (2013).

However, these studies are all primarily based on human behaviour and landscapes observed over the last 50 years, and any extrapolation further back in time is conjectural. Spatially, these observations are also constrained to the arid parts of Australia, and their applicability elsewhere has yet to be established. Further, this ethnographic work suggests that anthropogenic burning was extremely localised and with only transient biotic impacts (e.g. Bowman et al., 2008; Burrows et al., 2010), and therefore may not be easily discernable in palaeoenvironmental (e.g. palynological or charcoal) records. Few attempts have been made to directly correlate archaeological and palaeoenvironmental records, and for the most part any relationship remains equivocal (e.g.; Head, 1989; Black and Mooney, 2006; Mooney et al., 2007, 2011; Bird et al., 2013). Mooney et al. (2011) standardized and compiled charcoal records from 223 sites across Australasia producing a record of biomass burning for the last 70 ka. The lack of significant change in fire at about the accepted time of the human colonization of Australia (~50 ka), as well as the lack of congruence between a subset of the archaeological data used in this paper and the fire record led Mooney et al. (2011) to conclude that fire activity in Australia was unlikely to reflect human activity.

We explore the potential relationship between people and fire in Australia over 20,000 years with the most comprehensive continent-wide archaeological and charcoal datasets currently available. We analyse these proxies with statistically robust techniques that have not previously been applied to comparable palaeoenvironmental or archaeological data. Our primary aim was to test if anthropogenic burning could be discerned, and if so when it was initiated. We first test these concepts at a continental scale and then repeat this analysis on the southern portion of the continent, which is arguably more climatically homogenous, where prehistoric populations have been described as larger and more sedentary (Williams, 2013; Williams et al., in press), and where our datasets are strongest.

2. The proxies and their interpretation

2.1. Charcoal

The abundance of charcoal in sediments is widely used as an indicator of past fire activity (e.g. Patterson et al, 1987; MacDonald et al, 1991) and has been used to reconstruct fire histories at more than 700 sites across the globe (Daniau et al., 2012). The use of charcoal as a proxy of fire dates to Iversen (1941), and primarily relies on the optical identification and quantification of charcoal in sediments. Significant advances in charcoal methods have placed the discipline on a quantitative footing, exploiting the accumulation (*aka* influx) of charcoal (either no./cm^2/year or mm^2/cm^2/year) in sediments; the statistical analysis of these data allowing the derivation of fire frequency through time (Whitlock and Millspaugh, 1996; Long et al, 1998); and most recently methods allowing the synthesis of multiple charcoal records across a variety of spatial scales (e.g. Power et al., 2010; Marlon et al., 2013).

While widespread, the interpretation of charcoal data can be complex (e.g. Conedera et al., 2009). As a proxy of past fire events, it is confounded by several inter-connected issues: the taphonomy of charcoal (including the transport, delivery and preservation) is not consistent and can be dependent on the nature of the fire, post-fire events, spatial relationships involving fire-to-catchment size ratios, and proximity of the fire to the site of deposition. The inter-connected components of a fire regime can also influence charcoal accumulation and hence confuse the interpretation of any record. In Australia, the prehistoric fire regime is often characterized as consisting of regular, small fires, for example in a complex mosaic of burnt and unburnt vegetation. This might mean that fire is ubiquitous but not necessarily 'visible' in a charcoal record, unlike human use of fire in the post-European landscape, which shows up clearly in Australian paleofire data (Marlon et al., 2013). Frequent fire may also influence vegetation (e.g. fuel loads and type) and perhaps lead to less intense fires, or more grass and hence lower charcoal production. This ambiguity is starkly evident in the landmark chapter of Singh et al. (1981) in Fire and the Australian Biota, which is the first publication to discuss charcoal records across multiple sites in Australia. In this work the complex interplay between charcoal, fire frequency and fuel loads meant that an increase in charcoal was interpreted as an increase in fire activity at one site (Lake George) and less fire at another (Lashmar's Lagoon). To overcome this, here we consider any change in charcoal (not just an increase or decrease) in the statistical examination of the relationship between fire and people.

2.2. Archaeological radiocarbon data

As a proxy for Aboriginal demography, we use radiocarbon data from archaeological sites across Australia. This 'dates as data' approach is becoming increasingly commonplace in the archaeological literature, and recent work has continued to improve its reliability (e.g. Smith et al., 2008; Williams et al., 2008, 2010; Collard et al., 2010; Peros et al., 2010; Buchanan et al., 2011; Williams, 2012, 2013; Shennan et al., 2013). Nonetheless, analysis and interpretation is complex and has several limitations. In Australia, the two main criticisms of the technique include the following: 1) how detrital charcoal in archaeological sites (i.e. samples not recovered from features directly attributable to humans such as hearths, burials, etc) relates to the archaeological record; and 2) whether the radiocarbon data reflects demographic change, or changing behaviour in hunter–gatherer societies (i.e. more dates equals greater mobility, rather than more people). Recent work by Williams (2012, 2013) has addressed these issues and demonstrated that detrital charcoal data correlates well with other radiocarbon data directly attributable to human activity within archaeological sites and can be reliably used; and that the radiocarbon data correlates well with other archaeological indices (such as artefact discard rates), and provides greater certainty that the data reflects demographic change. Here, we similarly assume the data can be broadly attributed to demographic change and our confidence is bolstered by trends in the Australian data that seemingly closely reflect potential forcing factors (e.g. independent palaeoclimatic information).

3. Materials and methods

3.1. Charcoal

We use a new compilation of charcoal data representing sites within Australia (n = 155) (Fig. 1): these are a subset of the Australasian data of Mooney et al. (2011), supplemented with 6 new sites (see Supplementary data). In some cases (10 sites, detailed in the Supplementary data), the data have been slightly revised (for example resulting from improved chronological control) compared to that used in Mooney et al. (2011). We also developed a regional subset of these records (n = 125) located south of 25° (that is covering southern Australia, bound by the latitudes of 25–45° S and 110–155°E). The data consist of charcoal influx data from a wide variety of lakes and lagoons situated across the continent, although with a bias towards the eastern Australian coast (Fig. 1). As described in the Supplementary data, approximately 25% of the sites have a medium-to-high resolution (>15 samples/ka) and 42 of the sites (~27%) extend beyond 14 ka.

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