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Co-producing a fire and seasons calendar to support renewed Indigenous cultural fire management

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Abstract Indigenous knowledge emphasises the importance of cultural connections between humans and the biophysical world. In the face of threats to the maintenance and transfer of Indigenous knowledge, novel approaches such as seasonal calendars are emerging as tools to share knowledge and guide management of natural and cultural resources. The renewal of Indigenous cultural fire management in southeast Australia provided an opportunity to explore whether the co-production of a fire and seasons calendar, using Western and Indigenous knowledges, can support cultural fire management. We present a case study of cross-cultural collaboration between scientists and the Banbai Aboriginal rangers at Wattleridge Indigenous Protected Area, New South Wales. We reviewed literature from various disciplines (archaeological, ethnohistorical, Indigenous and ecological) and undertook participatory action research and interviews to collate relevant information. This was synthesised in *Winba = Fire, the Banbai Fire and Seasons Calendar*, which is used by the Banbai rangers to guide cultural burning, share cross-cultural knowledge and increase awareness of Indigenous cultural fire management. The process of co-producing knowledge, revitalising culture, caring for Country, working together and supporting self-determination is relevant for many Indigenous communities around the world.

Key words: cross-cultural science, cultural burning, knowledge co-production, seasonal calendar, traditional ecological knowledge.

INTRODUCTION

Indigenous knowledge encompasses 'people, language and culture and their relationship to the environment' (Gerry Turpin in Ens *et al.* 2015). Around the world, seasonal calendars have been created to collect and share Indigenous knowledge (Green *et al.* 2010) and to signify the connection between people, Country (ancestral estate) and the annual cycles of seasonal change on Country (James *et al.* 2018). Indigenous seasonal calendars have been used in the monitoring and management of water (Woodward *et al.* 2012), agricultural systems (Adjaye 1987; Jiao *et al.* 2012; Bhagawati *et al.* 2017; Saylor *et al.* 2017; Balehegn *et al.* 2019), climate change (Cochran *et al.* 2016; Chisholm Hatfield *et al.* 2018) and fire regimes (Armatas *et al.* 2016; McKemey *et al.* 2020a), and to guide eco-health decision-making (SantoDomingo *et al.* 2016). In Australia, there are at least 38 documented examples of Indigenous seasonal calendars (see Webb 1997; Hill *et al.* 2004; O'Connor & Prober 2010; Bodkin 2013; Turpin *et al.* 2013; Holmes *et al.* 2017; Clarke 2018; McKemey & Ngoorabul Community 2018; McKemey & Wahlabul Nation 2018). These seasonal calendars are generally based on phenological observations of local environments and linked to practices such as harvesting of traditional resources (Carpentaria Land Council Aboriginal Corporation 2013; Hatfield-Dodds 2016), which often relies on the ongoing intergenerational transfer of traditional ecological knowledge (TEK; Berkes 1993; Green *et al.* 2010). However, Indigenous knowledge is under threat globally (United Nations 2019; Chapman & Schott 2020) and seasonal knowledge is underutilised in natural resource management (Prober *et al.* 2011). Franco (2015) suggested 'it is time to initiate more projects that would focus on the relevance of calendars in ecosystem management'.

Indigenous people's TEK was passed on orally through the everyday experiences of hunting and gathering and moving through landscapes, as well as through storytelling and ceremony (Kovach 2010; McKemey *et al.* 2020a). The Australian Bureau of

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Meteorology (2016) stated 'This type of archiving is fragile as it is intrinsically linked to language, cultural practices and social values.' European colonisation of Australia in 1788 disrupted the intergenerational transfer of TEK, including that related to seasonal knowledge and use of fire (Eriksen & Hankins 2014). At the time of colonisation, the Australian landscape was a heavily curated cultural landscape – the product of millennia of active maintenance by its Indigenous custodians (Bowman 1998; Gammage 2011; Fletcher *et al.* 2020). Fire was an important tool that was used by Indigenous peoples for a variety of purposes, including to: communicate; clear the ground; hunt and gather; regenerate and protect resources (totems, foods, medicines and materials); provide illumination; and for cooking, warmth and ceremony (Jones 1969; Pascoe 2014; Cahir & McMaster 2018). Following colonisation, fire management was dominated by Western approaches of fire suppression and exclusion (Eriksen & Hankins 2014). However, recently political and academic attention has focussed on the use of Indigenous fire management as an alternative (Robinson *et al.* 2016; Maclean *et al.* 2018; Eloy *et al.* 2019; Nikolakis & Roberts 2020). Many Indigenous communities, particularly in southeast Australia, are in the process of reinvigorating cultural fire management (Maclean *et al.* 2018; Smith *et al.* 2018; Ngurra *et al.* 2019; Neale *et al.* 2019; Weir & Freeman 2019; Firesticks Alliance Indigenous Corporation 2020; McKemey *et al.* 2020b). 'Cultural burning' is a term mostly used in southeast Australia regarding the application of fire, defined as 'burning practices developed by Aboriginal people to enhance the health of the land and its people' (Firesticks Alliance Indigenous Corporation 2019). 'Cultural fire management' encompasses broader cultural practices, values, heritage and land management activities, including the spatial or temporal exclusion of fire (Office of Environment & Heritage 2016; McKemey *et al.* 2020b). Public interest in cultural burning in Australia increased significantly following the 'Black Summer' bushfires in 2019–2020 (McKemey *et al.* 2020b) and subsequent bushfire inquiries, which recommended that governments increase engagement and application of Indigenous cultural fire and land management (Binskin *et al.* 2020; Owens & O'Kane 2020).

In recent decades, acceptance and opportunities for Indigenous people to practise and revive customary management on ancestral Indigenous lands have gradually increased, following significant advances in recognition of Indigenous people's rights and self-determination (Altman & Kerins 2012). This has lead to the creation of Australia's world renowned Indigenous Protected Area (IPA) and Indigenous Ranger programmes (Australia State of the Environment Committee 2011; Hill *et al.* 2013; Social Ventures Australia 2016) and enhanced Indigenous engagement in natural resource management and biodiversity conservation (Barber & Jackson 2017). As a result, cross-cultural monitoring and knowledge co-production using Indigenous and Western knowledge systems is increasingly being adopted in research and the adaptive management of protected areas (Ens *et al.* 2015).

Knowledge co-production is a model defined as 'the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or system-oriented understanding of that problem' (Armitage *et al.* 2011: 996). This method is inherently transdisciplinary and weaves unique knowledge systems and observations together to produce holistic understanding (Armitage *et al.* 2011; Chapman & Schott 2020). Tengö *et al.* (2017) developed a process to bridge knowledge systems, which was customised for use in Australia by Ford *et al.* (2020), and includes the key steps of: strengthen and prepare, communicate, discuss, bring together and apply. Recent examples of knowledge co-production include the CSIRO *et al.* (2019) and Bundjalung people's co-development of the Arakwal Seasonal Planning Calendar (Bundjalung of Byron Bay Aboriginal Corporation (Arakwal) *et al.* 2019) and research by Hill *et al.* (2020) to support Indigenous climate change adaptation pathways. This coevolution of knowledge is an approach based on trust, respect, mutual learning and open mindedness, and includes the objectives of capacity building, empowerment, self-determination and strengthening of Indigenous knowledge as strategic endpoints (Chapman & Schott 2020).

Several studies have sought knowledge of traditional Indigenous practices to inform contemporary bushfire and ecosystem management (Raymond *et al.* 2010; Ray *et al.* 2012; Bardsley *et al.* 2019; Thomassin *et al.* 2019; Nikolakis & Roberts 2020). This paper aims to further this literature by asking the question: Can the co-production of a fire and seasons calendar, using Indigenous and Western knowledges, support cultural fire management? Using a case study of the Banbai Aboriginal rangers at the Wattleridge IPA, we aimed to answer this question by synthesising data from various knowledges (archaeological, ethnohistorical, Indigenous and ecological) to develop a fire and seasons calendar and explore applications for contemporary cultural fire management.

METHODS

Study site

Wattleridge IPA (480 ha) was the first declared in New South Wales (NSW) in 2001, and is located on the ancestral lands of the Banbai Aboriginal Nation in the New England Tablelands bioregion (Thackway & Cresswell 1995;

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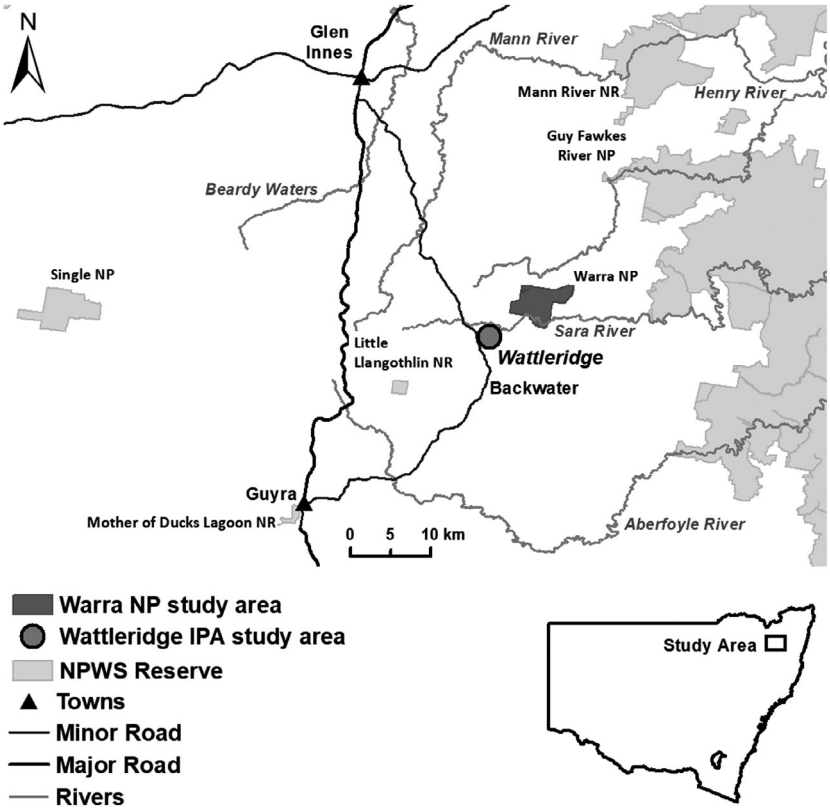

Fig. 1. The Wattleridge Indigenous Protected Area study site, and adjacent national parks (NP) and nature reserves (NR).

Patterson & Hunt 2012; Fig. 1). The area of the Banbai Aboriginal Nation includes Guyra, Ben Lomond, Glencoe, Marowan, Mount Mitchell, Kookabookra, Wollomombi and the catchment area of the Boyd and Mitchell River systems (MacPherson 1903; Mathews 1903; Tindale 1974). Wattleridge IPA is managed by the Banbai rangers, primarily for the conservation of biodiversity and Indigenous cultural heritage (including Indigenous rock art) and its vegetation communities are primarily dry sclerophyll forests on granitic soils (Hunter 2005; Banbai Business Enterprises Inc. 2014; Milledge 2016). The Banbai Aboriginal Nation is relatively small, covering a land area of 6000 km^2 (Tindale 1974) and today, consists of one main family group of approximately 90 people, of whom 10 are recognised as Elders. European occupation of this area occurred from the 1830s onwards and 'the rapid displacement of the Banbai people from their homelands during the 19th century and the advent of agriculture prevented traditional burning, hunting and gathering cultural practices' (Sonter 2018: 31). From 2009, the Banbai rangers started to renew cultural fire management through engagement with Indigenous fire specialists, other Indigenous ranger groups, the Firesticks project and government agencies (Tamarind Planning 2017; McKemey *et al.* 2019).

Knowledge co-production approach

From 2014 to 2020, the Banbai rangers, Indigenous fire practitioners and Western scientists worked together to share and weave knowledge of the ecological and cultural changes that occured when cultural fire management was reintroduced into a long unburnt landscape at Wattleridge IPA. The methods aligned with the five steps of knowledge co-production described by Tengö *et al.* (2017) and Ford *et al.* (2020) and are described below.

Strengthen, prepare

A partnership between the Banbai rangers and Western scientists was established through the Human Research Ethics process, with prior, informed consent for Indigeous knowledge to be shared and used in the fire and seasons calendar and research project (approval numbers HE14-182, HE19-068). A literature review for the Wattleridge IPA and surrounding New England Tablelands bioregion was conducted to explore relevant documented information for the fire and seasons calendar. The following subjects were searched: fire response, phenology/breeding cycles and Indigenous use/TEK of plants and animals found at Wattleridge; as well as the climate, ethnography, history, archaeology and Aboriginal languages of the area. Additionally, fauna data from a 5-year study (2013–2017) at Wattleridge IPA was used (Milledge 2016). Banbai language and knowledge for key plants, animals, weather, objects and activities were drawn from the Banbai Language Booklet (Guyra Local Aboriginal Land Council 1998), which included the languages Banbai (E8: Baanbay) and possibly Enneewin (D24: Southern Anaiwan) as categorised under

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AUSTLANG (Australian Institute of Aboriginal & Torres Strait Islander Studies 2019).

Communicate

Research partners considered seasonal calendars produced elsewhere and developed aspirations for the Banbai fire and seasons calendar. Together, through meetings and visits on Country, the research group planned cultural burning and research activities throughout the study period.

Discuss

Through multiple iterations of action learning cycles (Kearney *et al.* 2013), data was collected and discussed within the research team. The literature review findings were discussed at regular meetings at the Wattleridge IPA and Banbai rangers' headquarters. To document Banbai knowledge and further explore seasonal cues, phenology and fauna of interest to the Banbai rangers, semi-structured interviews (Table 1) were conducted during participatory action research activities including cultural burning and ecological surveys (Sarantakos 2012; Babbie 2013; Woodward & Marrfurra McTaggart 2016). Interviews were recorded audio-visually and transcribed, and explored themes of cultural burning, seasonal knowledge and the development and application of a fire and seasons calendar (Appendix S1). Focus group meetings were held at the Banbai rangers' headquarters and concentrated on working through a layered circular calendar template (Firesticks Alliance Indigenous Corporation 2016) to fill in cultural fire activities and observations of seasonal changes throughout the year.

Bring together

Data from the literature review and participatory action research was synthesised to develop a set of biocultural seasonal indicators. These indicators were defined as predictable, obvious, seasonal events that may or may not be known as culturally significant (e.g. arrival or departure of migratory birds, breeding animals, flowering or fruiting plants similar to 'calendar plants' described in Clarke 2018; see also McKemey *et al.* 2020a). The biocultural seasonal indicators were aligned with fire conditions to provide guidelines for contemporary cultural fire management, and were presented in *Winba = Fire, the Banbai Fire and Seasons Calendar* (hereafter referred to as *Winba = Fire*). The visual design of the fire and seasons calendar was developed for Firesticks by Jacqueline Gothe, Sian Hromek, Lyndal Harris and Kerry Hardy.

Table 1. Participants in semi-structured interviews

Initials	Gender	Role	Ranger experience (years)
LP	Female	Elder & Ranger	12
MT	Male	Elder & Ranger	10
CP	Male	Ranger Supervisor	11
TP	Male	Ranger Supervisor	11
DC	Male	Ranger	10
DP	Male	Ranger	10
TrP	Male	Ranger	10
KP	Male	Ranger	9
JJ	Male	Ranger	4
PA	Male	Ranger	4

Apply

The information in *Winba = Fire* was used by the Banbai rangers to guide their adaptive cultural fire management at Wattleridge IPA, and by the research team to share cross-cultural knowledge and increase awareness of Indigenous cultural fire management.

RESULTS

Seasonal and fire data from archaeological and ethnohistorical records

Banbai people and seasonal movement

Most of the archaeological evidence discovered in the New England Tablelands region is relatively recent – dating from the last 9000 years – with most current archaeological dates within the last 5000 years. Eastern Australia was probably occupied much earlier but older sites have not yet been found in this region (Beck 2006). The archaeological consensus about the New England Tablelands is that prior to colonisation, Aboriginal occupation was sparse (Sonter 2018) and perhaps best summarised by Flood (1976: 47): '... in upland areas population decreases as the elevation increases and that population as a whole was lower than on the coast or inland plains' of NSW. Clayton-Dixon (2019) suggested that the New England Aboriginal population was relatively small due to cold weather and lack of sea or major rivers with fish, and estimated the population to be up to 1100–1200 people at the time of European colonisation. Evidence also suggests that although the New England Tableland was cold in winter it was not abandoned by Aboriginal custodians (Oxley 1820: 288–90 in Godwin 1990; Beck *et al.* 2015). The inhabitation was patterned, not random. Activities in the landscape were focused at places where people lived and worked (quarries, camp sites and ceremonial sites), with a preference for locales with clustered resources, such as lagoons, and also along tracks and pathways between sites used for both ritual and secular purposes (Beck *et al.* 2015). Food and material resources were exploited according to their availability, and people moved for social purposes as well. Some ceremonial places (such as bora grounds) were visited repeatedly by large groups of people (Gardner 1854),

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being parts of the landscape imbued with meaning (Beck *et al.* 2015).

Seasonal food resources

Historical records note that traditional foods included short-beaked echidna, kangaroo, wallaby, wallaroo, possums, 'flying squirrels' (native gliders), koala, bandicoot, bush rat, birds and their eggs, emu, parrots, parakeets, turkey, wild pigeon, quail, waterfowl, snakes, goannas, lizards, fish, eel, turtles and their eggs, crayfish, shellfish, moths, insect larvae and grubs, native bee ('sugar bag') honey, yams, roots, fruits, manna, wattle gum, nectar and the seeds of native grasses (for scientific names, see Appendix S2; Gardner 1854; Macpherson 1860; Cubis 1977; Bellshaw 1978; McBryde 1978; Bowdler 1981; Cohen 1987; Godwin 1990; Beck 2006; Sonter 2018; Clayton-Dixon 2019). According to Blomfield (1992), 60–70% of Aboriginal food was made up of a wide range of vegetables and seeds. In 1930, Dicky Nelson, an elderly Indigenous informant shared the 'tribe' name Ahnbi (a variant of Banbai) as meaning 'porcupine (short-beaked echidna) cooking all the time' (Sonter 2018).

Banbai use of fire

Most analyses of ethnohistorical records concluded that Aboriginal burning of the landscape was a regular practice in the New England Tableland during early settlement. Fire was noted as being a tool for hunting macropods and arboreal mammals, facilitating access, maintaining the landscape (e.g. as grasslands or yam fields) and manipulating resources (e.g. attracting prey animals to freshly burnt ground, Table 2; Norton 1972; Godwin 1990; Benson & Ashby 2000; Sonter 2018). Norton (1972: 9) claimed that 'the pioneers discovered that New England was characterised by a relatively stable grassland community of savanna woodland with a park-like appearance'. He went on to suggest that colonial disruptions to traditional Indigenous fire regimes changed the Tableland from a park-like grassland, grazed by marsupials and frequently but irregularly burnt, to a mixture of brush and savanna grazed mainly by ruminants (introduced cattle and sheep) and periodically burnt, often on an annual basis. Godwin (1990) investigated whether Aboriginal firing was necessary to produce the 'parklands' and concluded that Aboriginal burning of the landscape did play a part in maintaining a certain mosaic of vegetation (such as grasslands), if not actually creating it. We note that the New England Tableland is a complex of different vegetation types and Norton's (1972) comments were likely only applicable to the basaltic areas of the central plateau. Many parts of the Tableland could not have supported these open grassy woodlands and such 'parkland' areas could only occur in areas predisposed to such vegetation, such as in low-lying areas of cold air drainage and high water tables particularly on higher nutrient soils (Benson & Redpath 1997; Benson & Ashby 2000; Lunt & Morgan 2002; Hunter & Hunter 2016).

Based on limited explorers' notes, Benson and Ashby (2000) suggested that Aboriginal fire regimes in the New England Tableland may have reduced the number of saplings in the understorey, but there must have been sporadic regeneration events coinciding with appropriate climatic conditions. They stated that Aboriginal burning probably varied in different habitats and was probably less frequent away from access routes and in the rockier terrain of the granite regions (such as Wattleridge IPA). Today, these areas support a diverse shrub layer, many species of which require a variable regime of fires every 5–50 years to persist (Kenny *et al.* 2004).

In an analysis of ethnohistorical studies, Enright and Thomas (2008) presented evidence of the occurrence of both open forests and woodlands and dense shrubby vegetation communities during the early European settlement of southern Australia. They suggested that frequent Aboriginal burning may have been a feature of some ecosystems but not others across these landscapes, correlated with resource richness and Aboriginal population size at the time of European settlement. Some forests with an open and grassy understorey may have been natural, while others were maintained through the managed use of fire by Aboriginal peoples. Other forested areas had dense, shrubby understoreys and may have experienced fire regimes similar to those of today. Dry sclerophyll forest, of the type found at Wattleridge IPA, had a low fuel load, low to moderate resource (water, plants, animals) level, an intermediate to long natural fire interval (30–100 years) and consequently an 'intermittent or not actively managed' level of use of managed fire by Aboriginal peoples in the pre-European period (Table 1 in Enright & Thomas 2008).

Seasonal and fire data from Banbai interviews

Since colonisation, the transmission of traditional Banbai knowledge and cultural practice has been disrupted. As Banbai Elder and ranger Lesley Patterson explained: 'You passed on your culture, at your own risk. We were beaten for speaking our language ... Back in the day, my mother and her siblings spoke [Aboriginal] language. My grandmother and grandfather taught them language at a very young age. Others were never taught because by then my grandmother was a Christian and the missionaries told my grandmother that speaking and teaching language

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Table 2. Ethnohistorical references to Aboriginal burning practices on the New England Tableland and adjacent gorge country (derived from Godwin 1990)

Source	Observation	Time of year	Location	Comment	Reference
Oxley (1820: 290)	'The great number of fallen trees was in some measure accounted for by the men observing about a dozen trees on fire near this camp*, no doubt the more easily to expel the opossums, rats and other vermin which inhabit their hollows'	September	Limbri, Moonbi Ranges	Small-scale burning associated with hunting on the tablelands *Aboriginal camp of 8–10 men, plus women and children (Godwin 1990)	Oxley (1820), Godwin (1990) and Norton (1972)
Oxley (1820: 310)	'Numerous smokes arising from natives' fires announced a country well-inhabited'	Late September	Gorges	Possibly refers to camp fires in the gorges (Godwin 1990)	Oxley (1820) and Godwin (1990)
Henderson (1851, vol. 1: 232)	'At one time a distant fire led me to suppose that I was near... black camp (sic), but I soon found that the bush, had been on fire, and that the burning trees and logs were scattered all around'	June		Not definitely attributable to Aborigines, but description similar to Oxley's observation: natural cause unlikely as lightning strikes uncommon at this time of year (Godwin 1990)	Henderson (1851) and Godwin (1990)
Henderson (1851, vol. 2: 13)	'Large tracts of country are also frequently burned (sic) by the natives sometimes in hunting, at others by accident, from the dropping of sparks from their fire sticks'	–	Refers to the upper reaches of the Macleay River (Godwin 1990)		Henderson (1851) and Godwin (1990)
Irby (1908: 72)	'The country around three sides of [Bolivia] station is now on fire, and on some days we have it as dark here from smoke as you have from fogs in November. It is generally supposed that these large fires are caused by the natives dropping their fire sticks accidentally, and not from any design on their part of trying to burn the settlers out of their station. They sometimes burn the old grass off, in order that they may have a chance of killing the kangaroo when they go to feed on the young grass that springs up, and also when they think they are likely to be pursued they fire it to prevent their track being seen'	December 1842	Bolivia Station (between Guyra and Tenterfield)	Large-scale firing of countryside, but only presumed to be by Aborigines Definite use of fire for hunting purposes, but probably of a small-scale nature (Godwin 1990)	Irby and Irby (1908) and Godwin (1990)

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Table 2. *Continued*

Source	Observation	Time of year	Location	Comment	Reference
Mitchell (1848: 413)	'The omission of the annual periodical burning by the natives… kangaroos are no longer to be seen there; the grass is choked by underwood; neither are the natives to burn the grass… these consequences although so little considered by the intruders, must be obvious to the natives with their usual acuteness as soon as cattle enter their territory'	–			Sonter (2018)
Marsh (1851)	'The great [summer] heat is sometimes increased by the burning grass, which is generally lighted by the aborigines carrying fire about with them; these fires, when there is a wind, will burn for days, but if there is no wind, there is almost always a dew at night, which often puts them out. The sight of fires at night is sometimes magnificent, as whole ranges of mountains are lighted up by them. They have a great effect on the character of the country, as they burn many of the young trees, and thus prevent the forest from being too thick. All the country, except when heavily stocked with sheep, is sure to be burnt at least every two to three years … young acacias spring up luxuriantly where the fires have been under the trees'	–	New England Tablelands		Marsh (1867), Norton (1972), McDonald (1994) and Sonter (2018)

was the devil's word … Blackfellas didn't have any rights so we had to assimilate to white man's way. The white people didn't burn a lot. We only had a couple of acres but we would burn it in a mosaic pattern … We had to fall over with the matches, we had to be careful because if you started teaching anything and other people heard you, they could report you to the police … My mother would have been taken to jail and we would probably have been put in welfare.'

The Banbai people took ownership of Wattleridge IPA in 1998 and started to renew their cultural fire management from 2009, although, they felt that they weren't able to implement 'right-way' fire until they developed relationships with Indigenous fire mentors in 2014 and were able to 'learn from Country' (McKemey *et al.* 2019; Steffensen 2020; McKemey *et al.* 2021). This process was also supported by networking with other Indigenous communities participating in cultural fire renewal through the Firesticks Project (Tamarind Planning 2017) and practical support from government agencies such as the NSW Rural Fire Service.

The Banbai rangers' cultural burning at Wattleridge IPA generally uses low-intensity small-scale mosaic burns to reduce fuel hazard whilst maintaining key habitat features such as hollow logs and stag trees. Lesley Patterson explained: 'Until 2009, we didn't do any cultural burning at Wattleridge and then we started to reintroduce a few burns, which made the land a bit healthier. After the burning we saw more animals, more native plants coming through and very few weeds. We have to be careful

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not to make the *winba* [Banbai word for fire] too hot, after a hot *winba* the grass is destroyed and more weeds come back. Cool burning leaves habitat behind for animals, birds and plants. The canopy is sacred and we try not to burn it. My mother taught me how to put the *winba* out and to have respect for it. She used to burn every year'.

Lesley described how the biocultural seasonal indicators were identified for *Winba = Fire* (Fig. 2): 'We have been working together to develop *Winba = Fire*, going out on Country to look at the plants that are flowering and fruiting, the birds that are coming and going, what the wallabies are doing, the snakes becoming active in the warm weather... We burn in autumn and winter to make it safe for the Country and people, so it is not going into a wildfire – we can control the *winba* during the cooler months.'

On the subject of pre-colonial burning, the Banbai rangers felt that the 'old people's' (ancestors') movements were driven by climate and resource availability. Tremane Patterson explained: 'They never really lived in one spot for too long. Once their food source had run out they would move on. They would do a burn, let it all burn out, move somewhere else, once everything had grown back they would come back ... They walked through the land all the time, they lived off it, that's how they kept getting their food back, all their traditional foods and their bush medicines. It was a pretty unique tool for Aboriginal people to use.' Mervyn Torrens described his understanding of people's movements: 'I think with the old people it was more seasonal too. If it got too hot down the coast they moved up the hill or somewhere where it's cooler through summer. And up here it is just too cold in winter time; they would go back down the coast. I think it is a seasonal thing with all the old fellas.'

Ecological knowledge

Key observations related to seasonal changes and fire responses of fauna and flora are summarised in Table 3. Through the implementation of cultural burning and comparison with other fires (hazard reduction burning, wildfire) we observed and learned how fire impacts the ecosystems around Wattleridge IPA (McKemey *et al.* 2019; McKemey 2020; McKemey *et al.* 2021).

Data synthesis for *Winba = Fire*, the Banbai fire and seasons calendar

Banbai Elders shared some TEK for use in the calendar; however, they felt that much of this knowledge was not passed down by previous generations. Our literature review revealed potential traditional uses of some of the plants and animals found at Wattleridge IPA. Participatory action research generated cross-cultural ecological data. All of this knowledge has been drawn together to co-produce *Winba = Fire* (Fig. 2), which will continue to be a dynamic document that evolves as knowledge grows. In Table 3, we outline the weather conditions, key observations, biocultural indicators, Aboriginal language names and cultural burning guidelines that were derived from various knowledges and synthesised to co-produce *Winba = Fire*. For example, during summer, many plants are flowering and migratory birds are present; this is a hot time with heightened wildfire risk. Winter, when superb lyrebirds are calling and the *kukra* (short-beaked echidna) are forming breeding trains, is the time of year to undertake low-intensity mosaic burning according to the Banbai rangers, and may be positive for biodiversity. In October, when the native clematis is flowering, day temperatures are increasing and fuel can be dry, so this is an unpredictable time to light fires.

Does *Winba = Fire* calendar inform cultural burning?

The Banbai rangers felt that cultural burning and development of the *Winba = Fire* calendar had helped them to revitalise their culture, as Lesley Patterson explained: 'We are passing on knowledge that was passed down to us. We are passing it on to the next generation so they know how to burn properly and have healthy Country to pass on to the generation after them. With *Winba = Fire*, because we know what is getting around in different seasons, we are not destroying habitats or wiping out native animals and plants where a wildfire might have damaged them in the past. *Winba* is a good tool but it can also be destructive, and knowing how to work with *winba* is a benefit for the people, the Country and the animals. Cultural burning has given us a chance to get out on Country and get to know it better.'

All of the Banbai rangers agreed that *Winba = Fire* was important to them and rated their improvement in knowledge about fire and natural resource management as '10 out of 10'. All rangers felt proud that they had *Winba = Fire* and were keen to continue cross-cultural monitoring. According to Lesley Patterson, 'We are trying to pass on our knowledge, now that we can actually do it we are going to pass it on and hopefully that is just going to go on for years and generations to come'. She noted that this contrasted with the past when 'your Elders weren't allowed to teach you about your culture'.

The goal of the development of *Winba = Fire* was to: guide cultural fire management; assist in the

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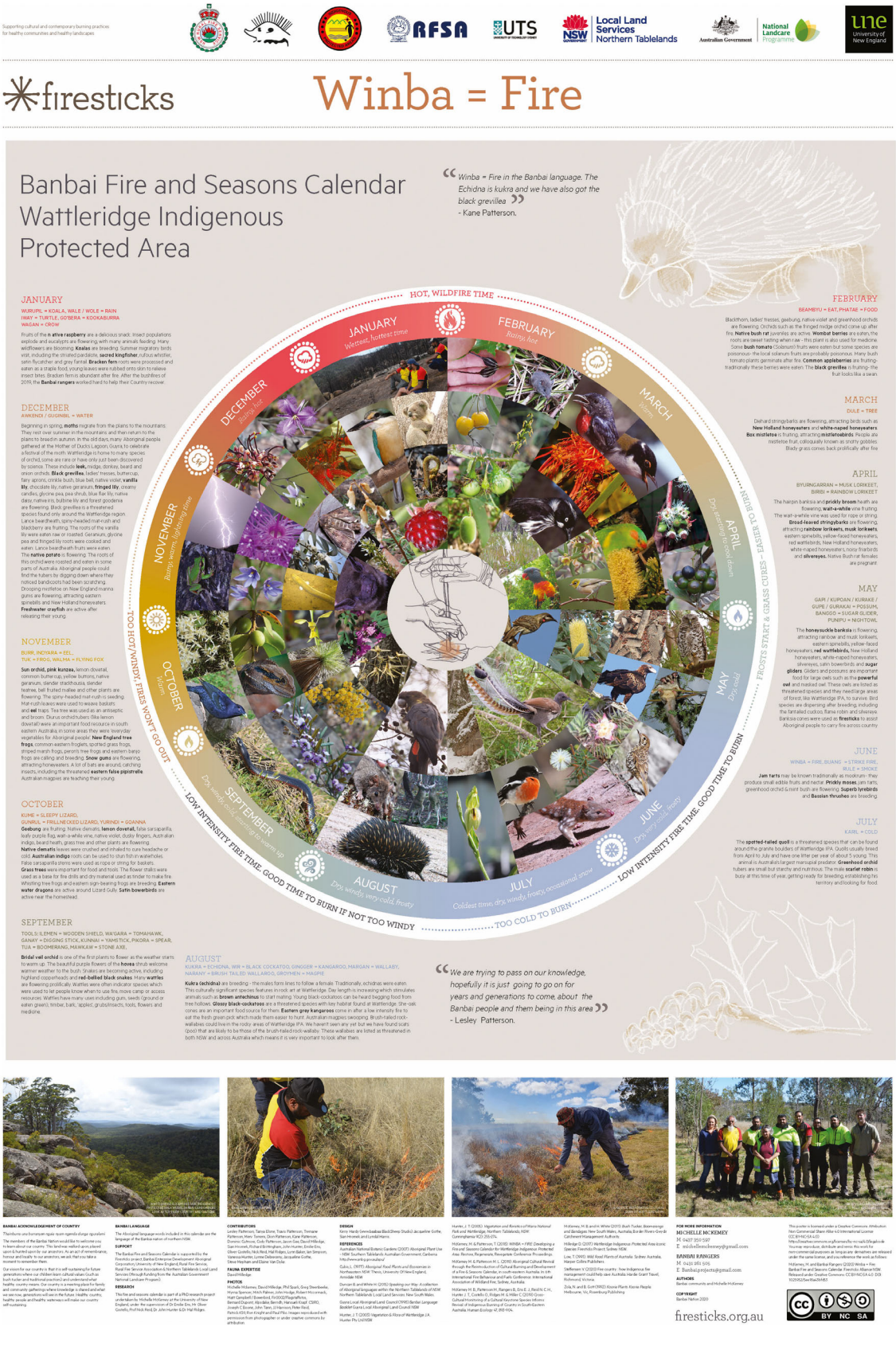

Fig. 2. *Winba = Fire*, Banbai Fire and Seasons Calendar (released under Creative Commons: CC BY-NC-SA 4.0. https://doi.org/10.25952/5ee18a43bfd53).

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Table 3. Key observations (scientific names listed in Appendix S2)

Months (Gregorian calendar)	Weather conditions (Bureau of Meteorology 2020)	Weather observations	Cultural burning guidelines	Key observations, examples of biocultural indicators	Potential use	Banbai language words (Guyra Local Aboriginal Land Council 1998)	References and sources of information
November, December	Mean rainfall 103–108 mm month^{-1} Mean maximum temperature 21–23°C Mean wind speed (9 am) 9.3–10.1 km h^{-1}, (3 pm) 10.2–10.7 km h^{-1} Mean relative humidity (9 am) 73–74%, (3 pm) 53–55%	Rainy, warm, lightning time Rainy, hot	Hot, wildfire time. Do not light fires	Many wildflowers and teatree are flowering. The spiny-headed mat-rush is seeding. Frogs are calling and breeding. Freshwater crayfish are active after releasing their young. Beginning in spring, moths migrate from the plains to the mountains. They rest over summer in the mountains and then return to the plains to breed in autumn Wattleridge is home to many species of orchid, including leek, midge, donkey, beard and onion orchids. Some orchids flower after fire. The native potato is flowering	Mat-rush leaves were used to weave baskets and eel traps. Teatree was used as an antiseptic and broom. Diurus orchid tubers (like lemon dovetail) were an important food resource in southeast Australia; in some areas they were 'everyday vegetables for Aboriginal people'. In the old days, many Aboriginal people gathered at the Mother of Ducks Lagoon, Guyra, to celebrate a festival of the moth. The roots of the vanilla lily were eaten raw or roasted. Geranium, glycine pea and fringed lily roots were cooked and eaten. Lance beardheath fruits were eaten. The roots of the potato orchid were roasted and eaten in some parts of Australia	*Burr*, *indyara* (eel), *tuk* (frog), *walma* (flying fox), *awkendi*, *guginbil* (water)	Banbai rangers; Cubis (1977), Zola and Gott (1992), Beck and Balme (2003), Hunter (2003), McKemey and White (2011) and Milledge (2016, 2017)
January, February	Mean rainfall 102–120 mm month^{-1} Mean maximum temperature 23–24°C Mean wind speed (9 am) 8.5–9.7 km h^{-1}, (3 pm) 9.3–10.0 km h^{-1} Mean relative humidity (9 am) 76–83%, (3 pm) 54–58%	Wettest, hottest time	Hot, wildfire time. May be too wet to light fires	Native raspberry, bush tomato, appleberry and black grevillea are fruiting. Many bush tomato plants germinate after fire. Insect populations abundant and eucalypts are flowering, with many animals feeding. Many wildflowers are blooming. Koalas are breeding. Summer migratory birds visit, including the striated pardalote, sacred kingfisher, rufous whistler, leaden and satin flycatcher and grey fantail. Bracken fern is abundant after fire. Blackthorn, ladies' tresses, geebung, native violet and greenhood orchids are flowering. Native bush rat juveniles are active	Bracken fern roots were processed and eaten as a staple food, young leaves were rubbed onto skin to relieve insect bites. Wombat berries were eaten, the roots are sweet when raw – this plant was also used for medicine. Some bush tomato (solanum) fruits were eaten but most species are poisonous- the local solanum fruits are probably poisonous. Many bush tomato plants germinate after fire. Appleberries were eaten	*Wurupil* (koala), *wale/wole* (rain), *iway* (turtle), *go'bera* (kookaburra), *wagan* (crow)	Banbai rangers; Zola and Gott (1992), Beck and Balme (2003), Hunter (2003), McKemey and White (2011), Martin (2014) and Milledge (2016, 2017)

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Table 3. *Continued*

Months (Gregorian calendar)	Weather conditions (Bureau of Meteorology 2020)	Weather observations	Cultural burning guidelines	Key observations, examples of biocultural indicators	Potential use	Banbai language words (Guyra Local Aboriginal Land Council 1998)	References and sources of information
March, April, May	Mean rainfall 50–70 mm month^{-1} Mean maximum temperature 14.5–21°C Mean wind speed (9 am) 9.0–9.7 km h^{-1}, (3 pm) 9.6–9.9 km h^{-1} Mean relative humidity (9 am) 79–83%, (3 pm) 56–59%	Warm weather in March gradually transitioning to cooler, drier weather in May	Frosts start in late April and the grass cures which makes it easier to burn. Beginning of low-intensity fire time	In March, diehard stringybarks are flowering, attracting birds such as New Holland and white-naped honeyeaters. Box mistletoe is fruiting, attracting mistletoebirds. Blady grass comes back prolifically after fire. In April, hairpin banksia and prickly broom heath are flowering; wait-a-while vine is fruiting. Broadleaved stringybarks are flowering, attracting rainbow lorikeets, musk lorikeets, eastern spinebills, yellow-faced honeyeaters, red wattlebirds, New Holland honeyeaters, white-naped honeyeaters, noisy friarbirds and silvereyes. Native bush rat females are pregnant. In May, the honeysuckle banksia is flowering, attracting rainbow and musk lorikeets, eastern spinebills, yellow-faced honeyeaters, red wattlebirds, New Holland honeyeaters, white-naped honeyeaters, silvereyes, satin bowerbirds and sugar gliders. Bird species are dispersing after breeding, including the fantailed cuckoo, flame robin and silvereye	People ate mistletoe fruit. The wait-a-while vine was used for rope or string, leaves were used for a medical infusion and fruit were eaten. Banksia cones were used as firesticks to assist Aboriginal people to carry fire across Country	*Dule* (tree), *byurngarran* (musk lorikeet), *biribi* (rainbow lorikeet), *gapi*, *kupoan*, *kurake*, *gupe*, *gurakai* (possum), *banggo* (sugar glider), *punipu* (nightowl)	Banbai rangers; Zola and Gott (1992), Beck and Balme (2003), Hunter (2003), McKemey and White (2011) and Milledge (2016, 2017)
June, July	Mean rainfall 50–55 mm month^{-1} Mean maximum temperature 10–11°C Mean wind speed (9 am) 10.2–10.6 km h^{-1}, (3 pm) 11.0–12.4 km h^{-1} Mean relative humidity (9 am) 84–86%, (3 pm) 59–63%	Dry, very cold, frosty, occasional snow	Low-intensity fire time, may be too cold to burn in July	Prickly moses, jam tarts, greenhood orchid and mint bush are flowering. Superb lyrebirds and Bassian thrushes are breeding. The spotted-tailed quoll breeds from April to July and has one litter per year of about 5 young. The male scarlet robin is busy getting ready for breeding, establishing his territory and looking for food	Jam tarts (*mookrum*) produce small edible fruits and nectar. Greenhood orchid tubers are small but starchy and nutritious	*Winba* (fire), *buang* (strike fire), *rule* (smoke), *karil* (cold)	Banbai rangers; Zola and Gott (1992), Beck and Balme (2003), Hunter (2003) and Milledge (2016, 2017)

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Table 3. *Continued*

Months (Gregorian calendar)	Weather conditions (Bureau of Meteorology 2020)	Weather observations	Cultural burning guidelines	Key observations, examples of biocultural indicators	Potential use	Banbai language words (Guyra Local Aboriginal Land Council 1998)	References and sources of information
August, September	Mean rainfall 52–57 mm month^{-1} Mean maximum temperature 12–16°C Mean wind speed (9 am) 11.9–12.2 km h^{-1}, (3 pm) 12.5–13.3 km h^{-1} Mean relative humidity (9 am) 71–78%, (3 pm) 51–52%	Dry, windy, very cold, frosty. From September, weather starts to warm up	Low-intensity fire time, good time to burn if not too windy	*Kukra* (echidna) are breeding: the males form a line to follow a female. Day length is increasing, which stimulates animals such as brown antechinus to start mating. Young black-cockatoos can be heard begging food from tree hollows. Eastern grey kangaroos come in after fire to eat the fresh green pick, which made them easier to hunt. Australian magpies swooping. From September, snakes are becoming active, including highland copperheads and red-bellied black snakes. Bridal veil orchid, hovea and wattles are the first plants to flower as the weather starts to warm up	Traditionally, echidnas were eaten. Wattles had many uses including gum, seeds (ground or eaten green), timber, bark, 'apples', grubs/insects, tools, flowers and medicine. Wattles were often indicator species which were used to let people know when to use fire, move camp or access resources	*Kukra* (echidna), *wir* (black cockatoo), *gingger* (kangaroo), *margan* (wallaby), *narany* (brush tailed wallaroo), *groymen* (magpie), tools: *ilemen* (wooden shield), *wa'gara* (tomahawk), *ganay* (digging stick), *kunnai* (yamstiick), *pikora* (spear), *tua* (boomerang), *mawkaw* (stone axe)	Banbai rangers; Zola and Gott (1992), Beck and Balme (2003), Hunter (2003), McKemey and White (2011), Milledge (2016, 2017) and Sonter (2018)
October	Mean rainfall 75 mm month^{-1} Mean maximum temperature 19°C Mean wind speed (9 am) 10.8 km h^{-1}, (3 pm) 11.1 km h^{-1} Mean relative humidity (9 am) 67%, (3 pm) 50%	Warm	From October it is getting warmer and the warm windy conditions can make it a risky time to burn – fires might not go out	Geebung are fruiting. Native clematis, lemon dovetail, false sarsaparilla, leafy purple flag, wait-a-while vine, native violet, dusky fingers, Australian indigo, beard heath, grass tree and other plants are flowering. Whistling tree frogs and eastern sign-bearing frogs are breeding. Eastern water dragons are active around lizard gully. Satin bowerbirds are active near the homestead	Native clematis leaves were crushed and inhaled to cure headache or cold. Australian indigo roots were used to stun fish in waterholes. False sarsaparilla stems were used as rope or string for baskets. Grass trees were important for food and tools. The flower stalks were used as a base for fire drills and dry material used as tinder to make fire	*Kume* (sleepy lizard), *gunrul* (frillnecked lizard), *yurindi* (goanna)	Banbai rangers; Zola and Gott (1992), Beck and Balme (2003), Hunter (2003), McKemey and White (2011) and Milledge (2016, 2017)

appropriate sharing and intergenerational transmission of Indigenous knowledge; act as a model for Indigenous and non-Indigenous partners to work together, and increase awareness of Indigenous cultural fire management. As demonstrated in this study, the Banbai rangers are applying the information in *Winba = Fire* to manage fire for the conservation of biodiversity and revitalisation of their culture. The Banbai rangers stated *Winba = Fire* provided an effective cross-cultural communication tool to share knowledge and increase awareness of Indigenous cultural fire management. The calendar was shared with primary, secondary and tertiary institutions, community groups, at scientific and fire management conferences and with many Indigenous communities across Australia. Lesley Patterson explained: 'We are using the calendar as a teaching tool – if we go anywhere we talk about the calendar and why it's important to us – so we are not burning at the wrong time… Even my youngest grandchildren are starting to pick up what I'm saying. They know about bush medicine.' The calendar is profiled on the Australian Government's Bureau of Meteorology (2016) Indigenous Weather Knowledge website and in the Atlas of Living Australia. The sharing of a blank template for a fire and seasons calendar allows other communities to develop their own calendars (Firesticks Alliance Indigenous Corporation 2016).

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Banbai ranger, Tremane Patterson, emphasised the need to work together: 'When the Elders teach culture it is your responsibility to hold that knowledge and keep passing it on. It is very important that we teach culture and share it with anyone who wants to learn, white or black, we are all in this together, we need to start learning how to manage Country as our old fellas did ... White and blackfellas, we have been working together for a while to learn from each other. If we don't start to move forward in this country as one, we are still going to be fighting every day to push for these things, it is breaking down barriers, learning from each other.'

DISCUSSION

Our study demonstrated that co-production of a fire and seasons calendar can guide renewed Indigenous cultural fire management at Wattleridge IPA, NSW. Several seasonal calendars have been published for other peoples and places, based largely on the documentation of TEK (Green *et al.* 2010; Kassam *et al.* 2011; Woodward *et al.* 2012; Hatfield-Dodds 2016). For example, on remote Indigenous-owned land such as Western Arnhem Land (Northern Territory), TEK has been the basis for the development of contemporary Indigenous fire management programmes (Garde 2009; Russell-Smith *et al.* 2009). However, in areas where colonisation has impacted the ability of Indigenous peoples to pass on or access TEK, alternative approaches need to be considered. In this study we demonstrated that archaeological, ethnohistorical, Indigenous and ecological knowledges can be combined through cross-cultural iterative action learning, to co-produce knowledge for application in a contemporary social–ecological system.

The co-development of our fire and seasons calendar used a diverse range of knowledges: archaeological, ethnohistorical, Indigenous and ecological. However, none of these sources of information were comprehensive enough to solely produce the Banbai seasonal and fire calendar, and some required caution in their interpretation. For the New England Tableland bioregion, we found no archaeological or palaeo-ecological information related to Indigenous fire regimes. Ethnohistorical evidence for Banbai occupation of the New England region was scarce due to several factors including low historical Indigenous population density; rapid displacement by European settlers; and because Indigenous inhabitants were wary of the arrival of Europeans who were relatively uninterested or unable to record what they observed of Indigenous culture (Bowdler 1981; Sonter 2018). Of the seven ethnohistorical references to fire in the New England bioregion detected in this study (Table 2), most were insufficient to describe past Indigenous fire regimes or to inform contemporary cultural fire management (Benson & Ashby 2000).

While the descriptions of Indigenous burning and influence on 'grassy parklands' at the time of settlement was consistent across local (Norton 1972; Godwin 1990; Sonter 2018) and wider (King 1963; Fletcher & Thomas 2010; Gammage 2011; Pascoe 2014) references, this may reflect the focus and bias of the observers towards higher fertility grassland areas. Many of the other vegetation communities of the New England bioregion, particularly those on the widespread lower fertility parent materials (e.g. granite, rhyolite, metamorphosed sediment) in addition to wet sclerophyll forests, rainforests, rock outcrops, lagoons and peat areas, may have been overlooked in the records of explorers and pioneers whose task it was to find the most fertile environments. The aforementioned communities are sensitive to fire frequency, seasonality, extent and intensity (Benson & Redpath 1997). Benson and Ashby (2000) concluded that some of the shrublands and dry sclerophyll forests on granite may have been subjected to intense fires every 10–30 years while the grassy woodland communities may have been subjected to a mosaic pattern of less intense and relatively frequent burning by Indigenous people.

Enright and Thomas (2008) suggested a generalised relationship between dry sclerophyll forest and an Indigenous fire regime that was 'intermittent or not actively managed'. However, the presence of Indigenous rock art and other cultural heritage sites at Wattleridge IPA (Sonter 2018) provide evidence that people were actively using the area and thus would have been burning at various spatial and temporal scales depending on cultural use and landscape type. While there may have been areas that Banbai people did not burn, the area would have laced with pathways, camps, ceremony areas and resources that they did burn. Actively not burning is also a form of cultural fire management (Firesticks Alliance Indigenous Corporation 2019).

Our research was limited by the relatively short time period during which it was conducted. While we were able to identify potential biocultural seasonal indicators, the timeframe may be insufficient to detect reliable, predictable biocultural indicators to guide cultural burning in the longer term, especially considering climate change (Green & Raygorodetsky 2010). We observed variations in the timing of indicators during the recent Australian drought and bushfires, which are consistent with changes noted by Indigenous communities elsewhere in a variable and changing climate (Petheram *et al.* 2010). Many areas of Australia, including the New England Tableland bioregion, exhibit often erratic rainfall patterns, which can lead to shifts in phenological responses

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over many months and years (Schultz *et al.* 2014; Morgan *et al.* 2017). Ecological and climatic changes associated with the Pyrocene (Pyne 2020) may make biocultural indicators less predictable, but monitoring these indicators provides greater opportunities for management responsiveness.

There is a risk that by producing the calendar and translating Indigenous knowledge into a format that is based on western scientific epistemology and communication, the deeper meanings and intergenerational connections of the knowledge will be disrupted (Barber & Jackson 2015). While the calendar offers one representation of Indigenous knowledge, it isn't necessarily the form it would take within that knowledge system, which might, for example, emphasise relationships and reciprocity rather than seasons (Russell *et al.* 2020). However, *Winba = Fire* is intended to become a living and evolving expression of cultural revitalisation. Indigenous knowledge, like that of other cultures, can be characterised as constantly evolving although based on a stable set of cultural Lores and relationships (Agrawal 2002; Rose 2005; Harmsworth & Awatere 2013). Indigenous knowledge comes from people's connection and understanding of kinship and Country. Building the *Winba = Fire* calendar enabled the process of knowledge evolution that is part of the process of (re)connecting to Country in a constantly changing socio-political and climatic world. The evolving nature of knowledge means it will remain relevant; for example, the calendar will change but Banbai will be aware of those changes if they maintain connection to, and all their links with, Country.

From this research, our experience and that of others, it is evident that cultural burning is more than just a technique to manage bushfire. The *Victorian Traditional Owner Cultural Fire Strategy* (The Victorian Traditional Owner Cultural Fire Knowledge Group 2019) describes fire as a tool to manage Country holistically. It is part of a suite of knowledges and practices that Traditional Owners are seeking to once again implement on Country to fulfil their cultural obligations to ensure the health of Country and people. For Indigenous people, cultural fire is about who makes decisions and how they are made (Weir & Freeman 2019; Neale *et al.* 2020b). Through this research we found that the reintroduction of cultural burning by Banbai rangers at Wattleridge IPA enabled cultural revitalisation, use of a threatened Indigenous language, intergenerational knowledge transfer, ecological restoration, hazard reduction and asset protection (including physical and cultural assets), responsible and appropriate fire management, community engagement and reconciliation. In light of recommendations from the 2020 bushfire inquiries (Binskin *et al.* 2020; Owens & O'Kane 2020), our case study illustrates how it is possible to gain a rich understanding of Indigenous fire culture and practice in southeast Australia, and could provide a practical 'how to' guide for future work in this area. The process of co-production of knowledge for cultural fire management described in this study could also be used by other communities, including those in settler colonial nations countries, such as the Americas and Africa (Christianson 2014; Eriksen & Hankins 2014; Moura *et al.* 2019; Thomassin *et al.* 2019).

Our research adopted a knowledge co-production (Hill *et al.* 2020) or coevolution (Chapman & Schott 2020) approach that linked to broader benefits, including cultural revitalisation and the generation of transdisciplinary, collective knowledge for enhanced management of Country. Chapman and Schott (2020) contended that, in the face of accelerated loss of Indigenous knowledge, researchers are in a unique position to support self-determination and empowerment of Indigenous peoples, and acceptance and preservation of their knowledge. Wyborn *et al.* (2019: 319) argued that co-production can contribute to societal transitions 'by shifting the institutional arrangements that govern relationships between knowledge and power, science and society, and state and citizens'. We concur that research must contribute to rebalancing social justice, through uncoupling research from colonially based hierarchies and power dynamics (Chapman & Schott 2020) and scaling up the use of co-produced decision-making frameworks in mainstream society (Wyborn *et al.* 2019). In the case of cultural burning, this could include the development of Indigenous-led, long-term research projects supportive of new and existing Indigenous fire management initiatives, examining the social, cultural, economic and ecological benefits of these initiatives (Neale *et al.* 2019; Neale *et al.* 2020a).

CONCLUSION

This study demonstrated the co-production of a fire and seasons calendar, using Western and Indigenous knowledges, and its use in guiding and promoting cultural fire management. This generated a transdisciplinary, collective knowledge, which, due to its dynamic and adaptive nature, is well-suited to the increasingly complex, volatile and unpredictable conditions of the Pyrocene. Such a process of renewing Indigenous cultural fire management, revitalising culture and caring for Country is relevant for many Indigenous communities around the world.

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AUTHOR CONTRIBUTIONS

Michelle McKemey: Conceptualization (equal); Data curation (lead); Formal analysis (lead); Funding acquisition (equal); Investigation (lead); Methodology (lead); Project administration (lead); Validation (equal); Writing-original draft (lead); Writing-review & editing (lead). **Banbai Rangers:** Conceptualization (supporting); Data curation (equal); Investigation (equal); Methodology (equal); Validation (equal). **Emilie J. Ens:** Conceptualization (equal); Investigation (equal); Methodology (equal); Supervision (equal); Writing-review & editing (equal). **John Hunter:** Data curation (equal); Investigation (equal); Methodology (equal); Supervision (equal); Writing-review & editing (equal). **Malcolm Ridges:** Investigation (equal); Methodology (equal); Supervision (equal); Writing-review & editing (equal). **Oliver Costello:** Conceptualization (equal); Funding acquisition (equal); Investigation (equal); Resources (equal); Supervision (equal); Writing-review & editing (equal). **Nick Reid:** Investigation (equal); Methodology (equal); Supervision (lead); Writing-review & editing (equal).

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may/can be found online in the supporting information tab for this article.

Appendix S1. Semi-structured interview questions.
Appendix S2. Scientific names.

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