

University of New England

***Developing cross-cultural knowledge ('right way' science)
to support Indigenous cultural fire management***

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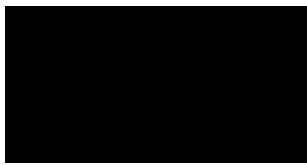
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Certification of Thesis

I certify that the substance of this thesis has not been submitted for any degree and is not currently being submitted for any other degree or qualification. I certify that, any assistance received in preparing this thesis, and all resources used, have been acknowledged in this thesis.



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Abstract

For millennia, Indigenous peoples have maintained relationships with their environments and managed resources through complex cultural systems. Over the last few centuries, in settler colonial nations, this connection has been and continues to be disrupted. In some areas, Indigenous cultural fire management was prevented and replaced with Western fire strategies such as fire suppression, exclusion and hazard reduction. Despite this, a global movement has begun to restore and renew Indigenous cultural fire management. This thesis investigates ways in which Indigenous rangers and Western scientists can work together to co-produce cross-cultural knowledge ('right way' science) to support and provide documented evidence for the benefits and challenges of Indigenous cultural fire management.

Indigenous cultural fire management has been re-established at the landscape scale across large areas of northern and central Australia. In southeast Australia, a renewal of Indigenous cultural fire management is underway. In Chapter 2, a systematic review of the academic and grey literature aimed to describe the current status of contemporary Indigenous cultural fire management in southeast Australia. Seventy documented cultural fire management projects were found with the potential for significant upscaling. Over the last decade, eight policies related to Indigenous fire management have been developed by state and territory governments in southeast Australia, with varying levels of implementation. Seventy-eight benefits and 22 barriers were identified in relation to cultural fire management. In the cases where cultural fire management has been successfully reinstated as an ongoing practice, Indigenous leadership, extraordinary relationships, strong agreements and transformational change were identified as drivers of success. For cultural fire management to grow, more funding, policy implementation, long-term commitment, Indigenous control and decision making, mentoring, training and research are required.

While recognition of Indigenous biocultural knowledge is increasing globally, processes for sharing and understanding Indigenous knowledge are limited, and could contribute to improved management of social–ecological systems. In Chapter 3, a case study was presented of the Yugul Mangi rangers of the South East Arnhem Land Indigenous Protected Area (IPA), Northern Territory. The aim of the study was to share Indigenous knowledge of fire, and develop a fire and seasons calendar to improve adaptive fire management and communication. We undertook participatory action research and semi-structured interviews

with rangers and Elders during 2016 and 2019. Results indicated that Indigenous rangers effectively used cross-cultural science (including local and Traditional Ecological Knowledge alongside Western science) to manage fire. Fire management was a key driver in the production of bush tucker (wild food) resources and affected other cultural and ecological values. A need for increased education and awareness about Indigenous burning was consistently emphasised. To address this, the project participants co-produced the *Yugul Mangi Faiya En Sisen Kelenda* (Yugul Mangi Fire and Seasons Calendar) that drew on Indigenous knowledge of seasonal biocultural indicators to guide the rangers' fire management planning.

In northern New South Wales, the Banbai people are in the process of renewing their cultural fire management at Wattleridge IPA. Chapter 4 described this reintroduction of cultural burning and its impact on the cultural keystone species, the short-beaked echidna (*Tachyglossus aculeatus*). Banbai rangers and non-Indigenous scientists conducted cross-cultural monitoring using a Before–After–Control–Impact (BACI) experimental design to measure echidna activity and key habitat features. Results indicated that the low intensity cultural fire in Wattleridge IPA did not impact the echidna or its habitat, whereas a nearby higher intensity fire in Warra National Park reduced echidna foraging area, possibly to avoid predation.

Cross-cultural monitoring and BACI design was also used to monitor the impact of cultural burning versus wildfire on the threatened plant, Backwater grevillea (*Grevillea scortechinii* subsp. *sarmentosa*) at Wattleridge IPA. As described in Chapter 5, cultural burning resulted in less mature grevillea mortality and less impact on reproductive output than wildfire. Both fires stimulated a mass germination event but the cultural burn preserved a multi-aged population while the wildfire killed 99.6% of mature shrubs. Careful management is needed to avoid local extinction of the grevillea following the impact of wildfire. In this case, the Banbai rangers adopted the grevillea into their cultural management framework in order to conserve it. Quantitative assessment of fuel load changes resulting from cultural burning, hazard reduction and wildfire indicated that fuel loads were reduced by all fire treatments, although the cultural burn was less severe than other fires.

Chapter 6 aimed to synthesise evidence from various knowledges (archaeological, ethnohistorical, traditional Indigenous, ecological, cross-cultural and local) to co-produce *Winba = Fire* (Banbai Fire and Seasons Calendar). This chapter demonstrated the sharing

and weaving of different knowledge systems through numerous iterations of action learning cycles to form a multiple evidence base to guide the Banbai rangers' cultural fire management at Wattleridge IPA.

The aim of Chapter 7 was to compare the impact on dry sclerophyll vegetation of cultural burning at Wattleridge IPA with hazard reduction burning at Warra National Park. Composition, cover, abundance and species richness of dry sclerophyll vegetation was compared using a BACI design. This study found that low severity cultural burning and moderate severity hazard reduction burning did not have a significant impact on full floristics or herbaceous vegetation. Only the hazard reduction burn had a significant impact on shrub and juvenile tree (woody species) cover and composition. The abundance of woody species was significantly affected by both fires, driven by a mass germination of 'seeder' species, particularly after the cultural burn. The long unburnt fire regime at Wattleridge IPA may have made vegetation communities more responsive to fire than the more frequently burnt vegetation at Warra National Park, such that the cultural burn had a greater impact on woody species abundance.

In conclusion, this study provided quantitative and qualitative evidence of some of the cultural, social, ecological and wildfire management outcomes of Indigenous cultural fire management. Cultural burning promoted regeneration, did not burn the canopy, reduced fuel loads and had less impact on wildlife habitat than other fires. Cultural burning brings not only a practice of fire management, but a holistic philosophy that underpins how land, wildlife, people and the cosmos interrelate. This study was limited to two case studies and provided locally specific results, which could be transferable and investigated on a larger scale through an expanded research program. Future research should prioritise supporting Indigenous research priorities and methodologies, which have been clearly articulated. This study demonstrated that Indigenous cultural fire knowledge and practice is alive, even in areas where the impacts of colonisation were severe, and is able to be renewed under supportive circumstances. This process of revitalising culture, caring for Country and co-producing knowledge is relevant for many Indigenous communities around the world. With wildfire issues escalating, Indigenous fire and land management is now recognised, locally and globally, as one component of a multi-faceted solution, which must also address issues such as climate change and disaster management. The transdisciplinary, collective knowledge co-produced through this study will be well-suited to increasingly complex, volatile and unpredictable conditions of the Pyrocene, due to its dynamic and adaptive nature.

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Note to the examiners

The thesis has been written in the style of a thesis by publications. The formatting aligns with that suggested by the University of New England for consistency. As Chapters 2 to 7 have been prepared as manuscripts, there is some repetition, for which I apologise in advance.

Approvals

Relevant approvals have been obtained for this research including Human Research Ethics (approval numbers HE14-182 and HE19-068), *National Parks & Wildlife Act 1974* (NSW) scientific licence (SL101661) and Northern Land Council research permits (permit ID 62530 and 86574).



Please be advised that this thesis contains chapters which have been either published or submitted for publication.

The accepted version(s) of the following chapter(s) have been removed in accordance with copyright compliance requirements:

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Chapter 7: Impacts of Indigenous cultural burning versus hazard reduction on dry sclerophyll forest composition, abundance and species richness in southeast Australia

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Chapter 1. Introduction

1.1. Background

Globally, for millennia, Indigenous peoples have maintained relationships with their environments and managed resources through complex cultural systems (Rose 1996; Berkes 1999; Spurway 2018; Morrison 2020). These long-term, intimate connections have influenced some researchers to suggest that the more inclusive term ‘biocultural diversity’ would better serve conservation of linked biological and cultural diversity, both of which are facing threats and ‘extinction crises’ (Loh and Harmon 2014). Ongoing declines in biocultural diversity have prompted many initiatives and policies from global to local levels to increase opportunities for Indigenous people to engage in conservation pursuits (Leiper *et al.* 2018). Formal recognition of Indigenous peoples in conservation is increasing in many regions, leading to multiple benefits to communities and national and international biodiversity goals and obligations (Moller *et al.* 2004; Bohensky and Maru 2011; Weir *et al.* 2011; Ens *et al.* 2015; Ens *et al.* 2016; Garnett *et al.* 2018; Leiper *et al.* 2018; Fa *et al.* 2020; Strelein *et al.* 2020). However, there are also many challenges to collaborative and biocultural conservation such as exclusion or exploitation of vulnerable communities and potential assimilation of Indigenous knowledge into Western institutionalised knowledge (Smith 1999; Louis 2007; Mistry and Berardi 2016). It is important to recognise that Indigenous peoples in some nations continue to be marginalised and persecuted (Roy 2000; Clarke 2001; Bengwayan 2003; Colchester *et al.* 2007; Komey 2008; Inguanzo 2014).

Fire management is an area of significant progress towards mutually beneficial, collaborative biocultural conservation (Nikolakis and Roberts 2020). Wildfire management is an escalating issue globally, with economic, environmental, social and cultural consequences (Bowman *et al.* 2011; He *et al.* 2019; Williams *et al.* 2019; Ward *et al.* 2020). In fire-prone regions such as the Americas, Australia and parts of Asia and Africa, wildfire management presents a formidable ongoing challenge that must be urgently addressed. During 2019–20, southeast Australia experienced catastrophic ‘megafires’ (locally referred to as the Black Summer fires) that burnt almost 19 million ha, destroyed over 3,000 homes and killed 33 people (Filkov *et al.* 2020; Nolan *et al.* 2020; Wintle *et al.* 2020). Climate change is extending fire seasons around the world, which is expected to result in more frequent and severe fires (Bureau of Meteorology and CSIRO 2020; Filkov *et al.* 2020). This wildfire behaviour suggests that the world has entered a global fire age known as the ‘Pyrocene’ (Pyne 2019; Pyne 2020). In

Australia, Bowman (2003b) suggested that there have been three great ages of wildfires: wild (pre-human period), tame (managed through Indigenous cultural fire management) and feral (uncontrolled) fire. He suggested that the challenge for modern-day land managers is to once again tame fire to both reduce the loss of life and property but also to conserve biodiversity, which can only be achieved with a profound understanding of the long history of fire in Australia.

Over millennia, Indigenous peoples used, and in many places still use, fire for subsistence purposes as well as a wide variety of social, cultural, spiritual and environmental reasons (Pyne 1991; Lake 2007; Burgess *et al.* 2009; Gammage 2011; Russell-Smith *et al.* 2020). Fire is a powerful tool that Indigenous peoples use to maintain and manage environments and is inextricably linked to Indigenous people's wellbeing, kinship systems and culture (Boyd 1999; Yibarbuk *et al.* 2001; Wray and Anderson 2003; Storm and Shebitz 2006; Russell-Smith *et al.* 2009; Bilbao *et al.* 2010; Trauernicht *et al.* 2015; Ansell and Evans 2019). However, in many contexts, traditional Indigenous burning practices were disrupted due to colonisation (Eriksen and Hankins 2014), changing land uses and politics (Schmidt and Eloy 2020). Indigenous cultural fire management practices are being revived internationally, primarily in post-colonial systems like Canada (Miller and Davidson-Hunt 2010; Miller *et al.* 2010; Christianson 2014), the U.S.A. (Eriksen and Hankins 2014; Armatas *et al.* 2016; Lake *et al.* 2017), South America (Mistry *et al.* 2005; Sletto and Rodriguez 2013; Mistry *et al.* 2016; Rodríguez *et al.* 2018; Schmidt *et al.* 2018; Eloy *et al.* 2019a; Eloy *et al.* 2019b; Mistry *et al.* 2019; Schmidt and Eloy 2020), Africa (Moura *et al.* 2019) and Australia (Russell-Smith *et al.* 2009).

Indigenous cultural fire management takes a different approach to Western society's wildfire management strategies of fire exclusion, suppression and hazard reduction (Eriksen and Hankins 2014; Eloy *et al.* 2019a). 'Cultural burning', a term frequently used in southeast Australia, is defined as 'burning practices developed by Aboriginal people to enhance the health of the land and its people' (Firesticks Alliance Indigenous Corporation 2019), and is used to describe the application of fire. Indigenous 'cultural fire management' encompasses broader cultural practices, values, heritage and land management activities (Office of Environment and Heritage 2016; Maclean *et al.* 2018; McKemey *et al.* 2020b; Weir *et al.* 2020). The primary purpose of Indigenous cultural fire management often focuses on the maintenance of cultural protocol, ceremony, Lore (traditional Indigenous law) and responsibility for Country with the desired outcome to maintain the health of Country

(including plants, animals, soil, water and weather; Standley 2019). In contrast, hazard reduction burning undertaken by government agencies generally has the primary purpose of reducing ground biomass in order to reduce the hazard to life and property (Standley 2019).

Since the 1960s, academics have discussed and debated the relationship that Indigenous Australians have with fire, and its impact on the landscape. Seminal works include Jones (1969) *Fire Stick Farming*, Hallam (1975) *Fire and Hearth*, Horton (1982) *Aborigines, Fire and Australian Ecosystems*, Kohen (1996) *Aboriginal Use of fire in Southeastern Australia*, (Langton 1999) *Burning questions: Emerging environmental issues for Indigenous peoples in Northern Australia*, Bowman (1998) *The Impact of Aboriginal Landscape Burning on the Australian Biota*, and Russell-Smith *et al.* (2009) *Culture, Ecology and Economy of Fire Management in North Australian Savannas: Rekindling the Wurrk Tradition*. More recently, historian Gammage (2011) and Indigenous authors, Pascoe (2014), Fletcher *et al.* (2021) and Steffensen (2020), have shifted paradigms, particularly those of the broader public, regarding the role that Indigenous cultural fire management has played and can continue to play in modifying and managing Australia's landscapes.

In northern Australia, a contemporary cross-cultural savanna burning program has grown since the late 1990s, based on methods emulating customary Aboriginal fire management using modern tools (Yibarbuk *et al.* 2001; Russell-Smith *et al.* 2009; Ansell and Evans 2019). This program operates at a landscape scale, with over 30 Indigenous-owned and operated projects covering an area of 17.9 million ha of northern Australia (Indigenous Carbon Industry Network 2020). In southeast Australia, many Indigenous communities aspire to re-establish and grow cultural fire management (The Victorian Traditional Owner Cultural Fire Knowledge Group 2019), but substantial barriers have prevented widespread application of cultural burning (Maclean *et al.* 2018; Smith *et al.* 2018). The impacts of the Black Summer fires magnified public and government interest in Indigenous cultural fire management (Mawson 2020), with bushfire (wildfire) inquiries recommending increased government commitment to Aboriginal land management and cultural burning programs, and further research (Binskin *et al.* 2020; Owens and O'Kane 2020).

Over the past four decades globally and in Australia, an approach which combines Indigenous knowledge and Western science has been evolving, known as 'cross-cultural', 'two-way' or 'right-way' science (Yunupingu and Muller 2009; Ens 2012a; Bush Heritage Australia 2020). Cross-cultural approaches have contributed to informing and managing

socio–ecological issues, from local, fine-scaled biodiversity projects (Baker and Mutitjulu 1992) to large-scale ‘wicked problems’ such as climate change (Johnson *et al.* 2016; Hill *et al.* 2020b), wildfire (Chapin *et al.* 2008) and ecosystem management (DeFries and Nagendra 2017). Novel approaches, such as seasonal calendars based on Indigenous and Western scientific knowledge, are emerging as new tools to communicate and foster cross-cultural knowledge (Woodward *et al.* 2012; Cochran *et al.* 2016; Yang *et al.* 2019).

This thesis explores how Indigenous knowledge and Western science can be used together to monitor and manage ecosystems through cultural fire management. It describes cross-cultural research collaborations (‘right way’ science) used to monitor ecological and cultural changes associated with cultural burning, and to support Indigenous cultural fire management using two case studies with the Banbai people at Wattleridge Indigenous Protected Area (IPA) in New South Wales (NSW), south eastern Australia, and the Yugul Mangi people at South East Arnhem Land (SEAL) IPA in the Northern Territory (NT), northern Australia. These research partners were chosen in both northern and southeast Australia, in order to explore the application of cross-cultural science in different regional contexts. As Indigenous fire management programs are generally more widespread and longer established in northern Australia, the exploration of Yugul Mangi case study provides a useful framework for undertaking the Banbai study. During my PhD research, I collaborated with the Banbai Aboriginal rangers to explore the conservation of a culturally significant animal species (the short-beaked echidna *Tachyglossus aculeatus*), a threatened plant species (the Backwater grevillea *Grevillea scortechinii* subsp. *sarmentosa*) and dry sclerophyll forest communities through the application of cultural burning. With the Banbai and Yugul Mangi rangers, I developed fire and seasons calendars using cross-cultural knowledge, to guide the implementation of cultural fire management. I then drew on these collaborations to discuss the broader applications of cross-cultural monitoring and management, and the benefits of cultural burning in Australia. In this introductory chapter, I provide an overview of literature relevant to the thesis topics, describe the research aims and objectives, and provide an outline of the thesis.

1.2. Literature review

1.2.1. Biodiversity Conservation

Biodiversity, the diversity of life on earth, includes approximately 9 million types of plants, animals, protists and fungi; as well as nearly 8 billion people (Cardinale *et al.* 2012; Worldometer 2020). Biodiversity underpins ecosystem functioning and the provision of ecosystem services essential for human wellbeing. It provides for food security, human health and the provision of clean air and water; it contributes to local livelihoods, and economic development (Secretariat of the Convention on Biological Diversity 2020). At the first Earth Summit in 1992, the majority of the world's nations declared that human actions were degrading the Earth's ecosystems, eliminating genes, species and biological traits at an alarming rate. This observation led to the question of how such loss of biological diversity will alter the functioning of ecosystems and their ability to provide society with the goods and services needed to survive (Cardinale *et al.* 2012). Since then, the United Nations developed the Strategic Plan for Biodiversity 2011–2020, including Aichi Biodiversity Targets, with a vision of 'By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people' (Secretariat of the Convention on Biological Diversity 2020).

Conservation of biodiversity includes protection, enhancement and scientific management of biodiversity to maintain it and derive sustainable benefits for the present and future generations (Jaisankar *et al.* 2018). Biodiversity conservation relies on public conservation reserves and protected areas, as well as private and off-reserve conservation (Margules and Pressey 2000; Lindenmayer *et al.* 2010). While protected areas are fundamental for the conservation of biodiversity, traditional models for national parks (Schelhas 2010) have been criticised for extending colonialism into natural areas and perpetuating environmental and social injustices (Colchester 2003; Shoreman-Ouimet and Kopnina 2015). In recent decades a 'new paradigm' for protected areas has evolved through recognition of Indigenous people's rights and conservation policies that accept that Indigenous peoples may own and manage protected areas (Colchester 2004). A more inclusive concept of 'biocultural approaches' to conservation aims to lead to effective and just outcomes within different social–ecological contexts, and can serve as a powerful tool for confronting the rapid global loss of both biological and cultural diversity (Gavin *et al.* 2015).

1.2.2. Indigenous land rights and ‘caring for Country’

Globally, Indigenous peoples’ engagement in cultural and natural resource management is increasing as a result of recognition of their land and human rights, and broader recognition of Indigenous knowledge (Natcher *et al.* 2005; Houde 2007; Nakamura 2008; Hill *et al.* 2012; Langton *et al.* 2014; Farhan Ferrari *et al.* 2015; Garnett *et al.* 2018; Fa *et al.* 2020; Reed *et al.* 2020). This is supported by international policies such as the Convention on Elimination of All Forms of Racial Discrimination (1969), the Convention on Biological Diversity (1999), the Millennium Ecosystem Assessment (2005), the United Nations Declaration of the Rights of Indigenous People (2007), the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) (2012) and the Global Strategic Plan for Biodiversity 2011–2020. In general, policies promoting blends of biological and cultural conservation share the following key objectives: “(1) involve Indigenous Peoples in biodiversity conservation; (2) maintain and develop Indigenous knowledge and culture; (3) and recognize and promote Indigenous natural and cultural resource management and traditional knowledge” (Ens *et al.* 2016). These objectives are also reflected in Australia’s conservation policies in relation to the inclusion of Indigenous people, land and knowledge (Ens *et al.* 2016).

In Australia, there are over 250 Indigenous language groups, each with their own culture, customs, language and Lore (Horton 1994; AIATSIS 1996). The term ‘Country’ is used by Australia’s Indigenous peoples, to mean (Smyth 1994):

... place of origin, literally, culturally or spiritually. It can have the political meaning of ‘nation’, but refers to a clan or tribal area rather than a nation-state such as Australia. Country refers to more than just a geographical area: it is a shorthand for all the values, places, resources, stories, and cultural obligations associated with that geographical area. For coastal Aboriginal¹ peoples and Torres Strait Islanders, Country includes both land and sea areas which are regarded as inseparable from each other.

¹ The terms ‘Aboriginal’ and ‘Indigenous’ are often used interchangeably in Australia. ‘Indigenous’ is a generic term which can encompass all Indigenous peoples, including Aboriginal and Torres Strait Islander peoples in Australia.

Similar terms are used internationally, such as ‘territories’ in the Americas (Bilbao *et al.* 2019) or ‘whenua’ in Aotearoa (New Zealand) (Kawharu 2002). Indigenous peoples’ perspective and their care for Country is formed and informed by the ancient holistic knowledge systems of their people, and emphasises the interdependence between nature, people and culture (Kwaymullina and Kwaymullina 2010; Muir *et al.* 2010; Milgin *et al.* 2020; Russell *et al.* 2020). ‘Caring for Country’ is described as “Indigenous people’s land and sea management” but it also provides benefits for the social, political, cultural, economic, physical and emotional wellbeing of Indigenous people (Weir *et al.* 2011). Caring for Country is intricately linked to maintaining Indigenous people’s cultural life, identity, autonomy and health, which has flow-on effects for the wider community and environment for all Australians (Burgess *et al.* 2005; Garnett and Sithole 2007; Burgess *et al.* 2009; Hunt *et al.* 2009; Weir *et al.* 2011; Zander and Garnett 2011; Altman and Kerins 2012).

In Australia, from the 1960s, Indigenous land rights were formally recognised through legislation such as the *Aboriginal Land Rights (Northern Territory) Act 1976* (Cth), *Aboriginal Land Rights Act 1983* (NSW) and the *Native Title Act 1993* (Cth). Increased land rights led to a recoupling of Indigenous relationships with traditional lands and sea Country throughout Australia that had broken down since European colonisation in 1788 (Baker *et al.* 2001; Langton 2003; Levitus 2009; Ritchie 2009; Altman and Kerins 2012; Bohensky *et al.* 2013). In 2020, Aboriginal and Torres Strait Islander peoples’ rights and interests in land had been legally recognised for about 40 per cent of Australia’s land mass (National Indigenous Australians Agency 2020). The majority of freehold Aboriginal land is held in northern and central Australia (National Native Title Tribunal 2020). Native title rights comprise various residual rights related to traditional affiliations that have continued without extinguishment for the last two centuries since European colonisation (Australian Trade and Investment Commission 2020). Despite 45% of Australia’s Indigenous population residing in the south-eastern states (Australian Bureau of Statistics 2017), Indigenous peoples own proportionately less freehold land in these states. However, relatively large areas of land are in the process of being claimed as native title (National Native Title Tribunal 2020).

The role of Indigenous Australians in land management is formally recognised in Australia’s key piece of environmental legislation, the *Environment Protection and Biodiversity Conservation Act 1999* (Cth): “a partnership approach to environmental protection and biodiversity conservation [that recognises and promotes] Indigenous peoples’ role in, and knowledge of, the conservation and ecologically sustainable use of biodiversity”

(s.3[2][g][iii]). Indigenous land and sea management is supported by a variety of public and private sector funding programs (Hill *et al.* 2012; Metcalfe and Bui 2016; Pert *et al.* 2020). Investment in Indigenous environmental management programs in bioculturally diverse areas usually has the primary objective of providing environmental benefit, which often leads to ancillary economic and social co-benefits (Langton and Rhea 2005; Barber and Jackson 2017; Renwick *et al.* 2017; Garnett *et al.* 2018).

Increased formal involvement of Indigenous Australians in cultural and natural resource management was noted as one of four predominant trends in environmental management in the first decade of the 21st century (Australia State of the Environment Committee 2011; Bohensky *et al.* 2013; Hill *et al.* 2013). For example, Indigenous Protected Areas (IPAs) are areas of land and sea managed by Indigenous groups as protected areas for biodiversity conservation through voluntary agreements with the Australian Government. In 2020, there were 96 IPAs covering an area greater than 100 million ha, constituting 54% of the area of Australia's National Reserve System and employing 2,600 Indigenous rangers (Department of Environment and Energy 2019). The management of IPAs is based on the application of the Indigenous knowledge–practice–belief complex (Berkes 1999) in collaboration with funding bodies (governments and NGOs) and external stakeholders (such as scientists), consistent with IUCN's protected area definition and guidelines (Smyth 2015).

1.2.3. Indigenous knowledge and practice

Indigenous knowledge has been defined by academics in various ways (Christie 2007). From the 1980s, the terms 'traditional ecological knowledge' (TEK) and 'Indigenous knowledge' (IK) referred to 'a cumulative body of knowledge and beliefs handed down through generations by cultural transmission about the relationship of living beings (including humans) with one another and with their environment' (Berkes 1993; Gadgil *et al.* 1993). Subsequently, various terms have been suggested, such as 'Indigenous ecological knowledge' (IEK) and 'local knowledge' (Woodley 1991; Warren *et al.* 1995; Raymond *et al.* 2010; Rodríguez *et al.* 2018). Ens *et al.* (2015) defined the term 'Indigenous biocultural knowledge' (IBK) as a modified version of TEK and IEK, with an emphasis on the importance of cultural connections between humans and the biophysical world. Aboriginal co-author Gerry Turpin (Ens *et al.* 2015) further described IBK as 'knowledge that encompasses people, language and culture and their relationship to the environment'. Stemming from understandings developed through the IPBES, Hill *et al.* (2020a) used the term 'Indigenous and local

knowledge systems'. These are generally understood to be 'bodies of integrated, holistic, social and ecological knowledge, practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environments. Indigenous and local knowledge is grounded in territory, is highly diverse and is continuously evolving through the interaction of experiences, innovations and various types of knowledge (written, oral, visual, tacit, gendered, practical and scientific). Such knowledge can provide information, methods, theory and practice for sustainable ecosystem management. Most Indigenous and local knowledge systems are empirically tested, applied, contested and validated through different means in different contexts' (Hill *et al.* 2020a: 11). For the purposes of this thesis, we use the terms 'traditional ecological knowledge' to describe knowledge passed down through Indigenous cultural traditions; 'Indigenous knowledge' to describe knowledge held by members of the Indigenous community; 'Indigenous biocultural knowledge' as a knowledge generated through intimate connection between Indigenous people and their Country; and 'local knowledge' to describe knowledge held by a person with extensive knowledge and connection to an area.

Indigenous biocultural knowledge and practice drives caring for Country (Baker *et al.* 2001; Altman and Kerins 2012; Ens *et al.* 2015; Pert *et al.* 2015; Cahir *et al.* 2018). Many studies have demonstrated how Indigenous knowledge and customary practices have been applied for the conservation of biodiversity (Baker and Mutitjulu 1992), including threatened species of flora and fauna (Bowman *et al.* 2001; Yibarbuk *et al.* 2001; Verran 2002; Whitehead *et al.* 2003; Garnett and Woinarski 2007; McGregor *et al.* 2010; Ridges *et al.* 2020). At jointly-managed Arakwal National Park, Bundjalung Indigenous knowledge and cultural burning was applied for the conservation of the threatened Byron Bay orchid (*Diuris byronesis*) (CSIRO *et al.* 2019). Russell-Smith *et al.* (1997) described the traditional resources and fire management practices of Indigenous people in western Arnhem Land, and how they were linked through the annual seasonal cycle. Woodward *et al.* (2012) demonstrated how Indigenous knowledge was used regulate to customary aquatic resource use and inform water resource management. These three examples all used Indigenous knowledge of seasons, ecosystems, plants and animals for the conservation of natural resources. Furthermore, examples of cultural keystone (i.e. culturally significant) species demonstrate how a cultural management framework can, and has for many years, been used to inform land management practices, foster cross-cultural engagement and conserve biocultural diversity (Cristancho and Vining 2004; Garibaldi and Turner 2004; Si and Turpin 2015).

In contrast, Western science is built on knowledge that relies on established laws through the application of the scientific method to the study of phenomena. Its method begins with an observation and is followed by a prediction or hypothesis that has to be tested (Ngulube 2016). It tends to be text based, data driven, empirical, reductionist, hierarchical and dependent on categorisation, whereas Indigenous science does not strive for a universal set of explanations but is particularistic in orientation and often contextual (Christie 2006; Nicholas 2018; Chapman and Schott 2020). Indigenous knowledge is often gained through experience, transferred among individuals (especially from Elders to youth) by stories and direct teachings, and may evolve through experience and observations (Chapman and Schott 2020). It may rely on oral traditions, spiritual or holistic views of nature, and inherent trust in ancestors' knowledge is in contrast to the reductionist approach of Western science (Kovach 2010; Dale and Armitage 2011). Many studies have looked at ways to 'integrate' Western science and Indigenous knowledge (Gadgil *et al.* 1993; Agrawal 1995; Johnson *et al.* 2016; Kealiikanakaoleohaililani and Giardina 2016; Zanotti and Palomino-Schalscha 2016; Diver 2017; Abu *et al.* 2020).

1.2.4. Integrating Indigenous and Western science: Cross-cultural collaboration

Interest in the 'integration' of Indigenous, local or traditional knowledge and Western science, although contentious, has been accelerating in recent years (Nadasdy 1999; Rist and Dahdouh-Guebas 2006; Houde 2007; Wohling 2009; Barbour and Schlesinger 2012; Bohensky *et al.* 2013). Bohensky and Maru (2011) identified three key motivators driving knowledge integration. Firstly they described that diverse knowledges are essential for maintaining global biocultural diversity (Maffi and Woodley 2012; Tengö *et al.* 2014) and will only be appropriately valued and protected through integration that brings benefits to both scientists and local people interested in maintaining that diversity (Edwards and Heinrich 2006). Secondly, these types of knowledge contribute invaluable information for science and natural resource management, and they often fill gaps in understanding that science cannot (Baker and Mutitjulu 1992; Johannes 1998). Finally, recognition of traditional knowledge in natural resource management has importance beyond scientific or broader societal merit: it is tantamount to social justice, sovereignty, autonomy, and identity of Indigenous peoples (Agrawal 1995; Aikenhead and Ogawa 2007; Nelson *et al.* 2011).

Knowledge integration can be achieved through cross-cultural (or two-way) techniques, which are described as ‘using combinations of Indigenous and non-Indigenous knowledge and methods and with the involvement of both Indigenous and non-Indigenous people towards a common goal’ (Ens 2012a: 46). For examples of cross-cultural scientific collaborations see Ens *et al.* (2012), Brennan *et al.* (2012), Moorcroft *et al.* (2012) and Walsh *et al.* (2013). Cross-cultural monitoring is often used to assess natural and cultural values, and is increasingly being employed in decision making and adaptive management (defined as ‘learning by doing’; Walters and Holling 1990; Westgate *et al.* 2013), particularly in IPAs and co-managed national parks (Horstman and Wightman 2001; Hoffmann *et al.* 2012; Preuss and Dixon 2012; CSIRO *et al.* 2019; Russell *et al.* 2020). These approaches are ideally designed to maintain and build social–ecological resilience through ethical, productive and mutually beneficial relationships (Bohensky and Maru 2011). In 2020, the North Australia Indigenous Land and Sea Management Alliance and CSIRO released the *Our Knowledge Our Way in Caring for Country: Indigenous-led approaches to strengthening and sharing our knowledge for land and sea management. Best practice guidelines from Australian experiences* (Woodward *et al.* 2020). The vision established by the Indigenous-majority Steering Group, was: (1) Indigenous people are empowered to look after Country *our way*; and (2) improved environmental conditions and multiple social, cultural and economic benefits come from effective Indigenous adaptive management of Country (Woodward *et al.* 2020).

However, cross-cultural scientific collaboration is not applied as widely as Western science (Adams *et al.* 2014). Furthermore, in some cases cross-cultural collaborations have been criticised for being exploitative, extractive, exacerbating existing (post-colonial) power imbalances and requiring scientific ‘validation’ as a burdensome replication of Indigenous biocultural knowledge (Andersen 1999; Nadasdy 1999; Smith 1999; Stephenson and Moller 2009; Smith *et al.* 2018; Muller *et al.* 2019; Chapman and Schott 2020). Criticisms of knowledge integration include ‘a tendency among the scientific community to assimilate local ecological knowledge within Western worldviews of managing nature’ (Mistry and Berardi 2016); attempting to ‘distil’ Indigenous knowledge into static, transferrable and non-contextual forms which remove the localised essence of Indigenous knowledge; and to institutionalise Indigenous knowledge into dominant environmental governance structures (Agrawal 2002; Hemming *et al.* 2007; Louis 2007; Hemming *et al.* 2010; Ens *et al.* 2015).

‘Sharing and weaving’ rather than ‘integrating’ different knowledge systems as a multiple evidence base to develop innovative practices and solutions, is seen as a preferred approach (Tengö *et al.* 2014; Tengö *et al.* 2017; Woodward *et al.* 2020). 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 systems-oriented understanding of that problem’ (Armitage *et al.* 2011: 996). This method is inherently transdisciplinary and weaves unique knowledge systems and observations to provide a holistic understanding of a problem (Armitage *et al.* 2011; Chapman and Schott 2020). Likewise, knowledge coevolution 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 and Schott 2020). These models attempt to reconcile injustices between Western science, described as an academic system that has been ‘created as the epicentre of colonial hegemony’ (Shizha 2010), and Indigenous knowledge (Chilisa 2017; Chapman and Schott 2020). These efforts tend to participatory, decolonising and Indigenous research methods, which aim to empower Indigenous peoples as researchers (Braun *et al.* 2013; AIATSIS 2020; Hill *et al.* 2020b). This process of decolonisation seeks to reverse and remedy the power structures imposed by colonial invasion and their impacts, through direct action and listening to the voices of First Nations people (O'Dowd and Heckenberg 2020).

1.2.5. Indigenous fire management

Fire management has provided a rich setting for cross-cultural collaboration, particularly through the development of Indigenous savanna burning programs in northern Australia and revival of Indigenous cultural fire management globally (Ray *et al.* 2012; Russell-Smith *et al.* 2013; Sletto and Rodriguez 2013; Mistry *et al.* 2016; Ansell and Evans 2019; Nikolakis *et al.* 2020). Through their relationship with fire over 65,000 years, Indigenous Australians developed a sophisticated cultural fire management framework resulting in a heavily curated cultural landscape (Bowman 2003b; Russell-Smith *et al.* 2009; Clarkson *et al.* 2017; Ens *et al.* 2017; Fletcher *et al.* 2021). In the words of Indigenous leader Joe Morrison, ‘Fire is, and always has been, part of the interwoven matrix of the relations between people, the physical and spiritual world’ (Morrison 2020: 31).

Australia was colonised by the British from 1788, which had widespread and ongoing impacts on Indigenous peoples, including frontier warfare, massacres, violence, disease,

impoverishment, removal of Indigenous peoples from their traditional lands, the ‘stolen generation’ (children forcibly removed from their families), prohibition of cultural practices and languages, and transgenerational trauma (Blomfield 1992; McDonald 1996; Atkinson 2002; Elder 2003; Harris 2003; Hunter 2004; Roberts 2006; Clayton-Dixon 2019). Consequently, traditional Indigenous fire practices were disrupted and in some places prevented (Eriksen and Hankins 2014) although in some remote areas Indigenous peoples were able to maintain significant practice, ceremony and language (Gould 1971; Latz 1982; Haynes 1991; Russell-Smith *et al.* 1997; Bird *et al.* 2016; Bird 2019; Standley 2019). Some academics have concluded that in certain areas of Australia (e.g. southern Australia), the alienation of Aboriginal groups from their traditional lands means that repositories of traditional Indigenous fire management knowledge are mostly lost (Esplin *et al.* 2003). Others have suggested that although traditional Indigenous tools of fire management have changed (such as replacing burning on foot with helicopters), the traditional knowledge of how to burn has not, for example in relation to seasonality (Lewis 1985). The latter view is supported by evidence in Arnhem Land where patterns of fine-scale, regular fire use have been maintained or re-established by Indigenous communities (Yibarbuk *et al.* 2001; Gorman *et al.* 2007; Garde 2009). Indeed, the re-instatement of Indigenous cultural fire management has occurred across large portions of northern Australia (Robinson *et al.* 2016; Indigenous Carbon Industry Network 2020), stretching from the Kimberley in Western Australia (Legge *et al.* 2011; Vigilante *et al.* 2017), to central Australia (Edwards *et al.* 2008; Bliege Bird *et al.* 2012; Bird 2019) and Cape York in Queensland, eastern Australia (Perry *et al.* 2018; Standley 2019).

Several studies have described and analysed the integration of Western science and Indigenous knowledge through the application of modern savanna burning methods in northern Australia, and demonstrated associated ecological, cultural, social and economic outcomes (Whitehead *et al.* 2003; McGregor *et al.* 2010; Richards *et al.* 2012; Russell-Smith *et al.* 2013; Ansell and Evans 2019; Altman *et al.* 2020; Evans and Russell-Smith 2020). However, some studies have criticised modern savanna burning programs, suggesting that they may lead to outcomes such as: disempowerment, dissatisfaction and disassociation of Indigenous Traditional Owners; ‘bioperversity’; and a reduction in the complexity and contingency of Indigenous fire management applied as a fine scale mosaic, which has been replaced with larger fires with standardised goals (Martin 2013; Fache and Moizo 2015; Petty *et al.* 2015; Perry *et al.* 2018; Corey *et al.* 2019; Cramer 2019).

In southeast Australia, renewal of cultural fire management is underway, and many Indigenous communities aspire to re-establish and grow cultural fire management (Robinson *et al.* 2016; Maclean *et al.* 2018; Smith *et al.* 2018; Darug Ngurra *et al.* 2019; Neale *et al.* 2019a; Weir and Freeman 2019). Contemporary cultural fire management in southeast Australia is generally characterised by a holistic vision of burning that equates, in practice, to low severity patchy fires. The practice of Indigenous fire management across Australia is more diverse than this, depending on cultural, spatial and temporal variables (Thomson 1939; Thomson 1949; Lewis 1994; Altman 2009). This thesis mostly focuses on contemporary cultural fire management in southeast Australia, while using a case study in northern Australia to provide a framework for a more established, formalised Indigenous fire management program. While an extensive literature on Indigenous cultural fire management exists for northern Australia, in southeast Australia, this is an emerging field of research with few academic publications (Chapter 2). Indigenous cultural fire managers have sought support to produce research that translates and communicates the outcomes and holistic benefits of cultural fire management (Smith *et al.* 2018; Firesticks Alliance 2020). This provides an opportunity to contribute to a large research gap, and to apply cross-cultural techniques to promote ethical and mutually beneficial research.

1.2.6. Fire ecology and management

The Western scientific study of fire ecology has amassed a substantial body of literature, focussing on issues such as fire history, behaviour and regimes; plant, animal and community responses to fire; and fire management and policy (Whelan 1995; Bradstock *et al.* 2002; Lavorel and Garnier 2002; Cary *et al.* 2003; McKenzie *et al.* 2011; Bond and Van Wilgen 2012; Kozlowski 2012). Fire is a key driver of Earth's biodiversity (Bond and Keeley 2005; Bowman *et al.* 2009; Estes *et al.* 2011; He *et al.* 2019) and has been a major force shaping the distribution and form of Australian biodiversity and landscapes (Gill *et al.* 1981; Miller and Murphy 2017). Australia is among the most fire-prone of continents and fire is actively managed, either through firing or prevention, as an important tool to promote production and conservation goals (Pyne 1991; Russell-Smith *et al.* 2007b). Fire plays a vital role in the dynamics of many Australian ecosystems and often provides a critically important cue for regeneration of vegetation, liberation of resources such as nutrients and light, and by creating disturbance and open space (Keith 2004). Inappropriate fire regimes are a key threat to ecosystems and biodiversity, with ecosystem modification (including the impacts of changed fire regimes) listed as a threat for almost three-quarters of threatened taxa in Australia

(Kearney *et al.* 2019; Department of Planning Industry and Environment 2020c). The vegetation, topography and local weather conditions during a fire generate a landscape with spatial and temporal variation in fire-related patches (pyrodiversity), and these produce the biotic and environmental heterogeneity that contributes to biodiversity dynamics across local and regional scales (He *et al.* 2019). The concept that ‘pyrodiversity begets biodiversity’ stimulates ongoing debate (Parr and Andersen 2006; Kelly *et al.* 2015; Bowman *et al.* 2016; Corey *et al.* 2019; He *et al.* 2019). However, Trauernicht *et al.* (2015) found local and global pyrogeographic evidence that Indigenous fire management creates pyrodiversity, which shapes fire-prone ecosystems and has allowed human societies to cope with fire as a recurrent disturbance over much of Australia.

Ecosystems respond to and recover from fire in various ways, depending on factors such as climate, soil, topography, fire regime, human management and fire–vegetation dynamics (Miller and Murphy 2017). The frequency of fires, as well as their intensity, type, season of occurrence and extent, are collectively known as the ‘fire regime’ (Gill 1975), and these have a substantial effect on ecosystems and biodiversity (Bradstock *et al.* 2002). Fire-response processes and functional trait groups influence organism persistence across four levels of ecological organisation (individual, population, community, landscape). Fire regimes (frequency, intensity, season and type) and their spatial patterns and climate regimes influence processes at all levels of organisation, and also influence each other through fire weather patterns, fuel accumulation rates and greenhouse gas emissions (Gill 2012; Keith 2012).

Individual fires affect populations of plants and animals directly by causing death or injury and, in some cases, by providing stimuli for floral development, dry fruit dehiscence or seed germination. Fire regimes affect species, the most extreme effect being local extinction (Gill 2012). Studies on a small fraction of all species have advanced understanding of processes and plant traits that mediate fire responses at individual and population levels. Although this is essential for understanding and predicting plant responses at higher levels of organisation, important community and landscape processes are still poorly understood (Keith 2012). For most animals, knowledge is lacking across all levels of organisation. Given their trophic status, persistence is likely to be sensitive to processes and traits operating at community and landscape levels (Keith 2012). For example, as vegetation structure and composition change during post-fire succession, so too does the type, abundance and distribution of resources available to animals, including shelter, food and foraging microhabitats (Haslem *et al.* 2011;

Nimmo *et al.* 2014; Valentine *et al.* 2014; Nimmo *et al.* 2019). Many studies have stressed the importance of unburnt vegetation remaining within fire-affected areas as faunal refuges, and the potential for prescribed burning to contribute to refuge habitat if it avoids severe burning in a subsequent wildfire (Whelan *et al.* 2002; Robinson *et al.* 2013; Robinson *et al.* 2014; Croft *et al.* 2016). A better understanding of how fires interact with resource dependency and plasticity, dispersal, and the ability to persist at low densities in unsuitable habitat is essential for predicting fauna persistence under fire regimes (Keith 2012).

In their review of fire management for biodiversity conservation, Driscoll *et al.* (2010) identified three areas of required knowledge: (i) a mechanistic understanding of species' responses to fire regimes; (ii) knowledge of how the spatial and temporal arrangement of fires influences the biota; and (iii) an understanding of interactions of fire regimes with other processes. They identified a need for fire management to be applied in an adaptive management context but found little indication of the schedule of learning that might be needed to implement adaptive management. They concluded that developing ecologically sustainable fire management practices will require sustained research effort and a sophisticated research agenda based on carefully targeting appropriate methods to address critical management questions.

1.2.7. Ecology of species and communities

The literature under review in this section addresses specifically the regional southeast Australian context, commensurate with the main regional scope of this thesis.

1.2.7.1. Dry sclerophyll forest

Inappropriate fire regimes are considered a key threat to biodiversity, demonstrated by a global problem of biodiversity loss in fire prone temperate forests, especially in Australian woodlands and open forests (Catling 1991; Gill and Bradstock 1995; Whelan *et al.* 2002; Cary *et al.* 2003; Keith 2004; Whelan *et al.* 2009; Croft 2013). Too-frequent fire reduces species richness in vegetation types, and 'high frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition' has been listed as a Key Threatening Process under the NSW *Biodiversity Conservation Act* (BC Act) (Department of Planning Industry and Environment 2020c). On the other hand, many years without fire can lead to the senescence and dwindling of fire-dependent species (Williams and Gill 1995).

The fire response syndrome of plant species, whether sprouters or seeders, is a key life history trait with profound effects on post-fire population dynamics and community composition (Noble and Slatyer 1980; Gill 1981; Hunter 2003a; Clarke *et al.* 2009; Clarke *et al.* 2015). Fire regimes and fire threshold concepts consider the impacts of fire frequency on floristic composition and species abundance in vegetation types (Bradstock and Kenny 2003). Fire thresholds should vary within a lower and upper threshold to maintain species in a community (Watson 2006). Lower thresholds are derived from plant vital attributes (primary juvenile periods and regeneration modes) while upper thresholds are developed on the lifespan of adults and seed banks (Kenny *et al.* 2004). Similar studies and guidelines regarding the effects of fire on flora and fuels have been developed overseas, such as in the United States and Canada (Brown and Smith 2000; Spies *et al.* 2012).

The NSW *Guidelines for Ecologically Sustainable Fire Management* (Kenny *et al.* 2004) described fire interval domains for broad vegetation groupings and derives fire interval guidelines or thresholds based on broad ranging analyses of vital attribute information for vascular plant species known to occur in these vegetation groupings. For example, the dry sclerophyll shrub/grass forest formation consists of open eucalypt forests with sparse shrub stratum and continuous grassy groundcover (Keith 2004). The domain of acceptable fire intervals for grassy dry sclerophyll forest was calculated as 5 to 50 years, while some intervals in the higher end of the range (c. 25 years) are desirable (Kenny *et al.* 2004). The proposed fire intervals, derived from floristic analysis, are considered compatible with the requirements of threatened fauna with known fire response information (Kenny *et al.* 2004). Fuel accumulation is rapid in dry sclerophyll forest, with fuel loads of c. 10 t/ha reached within 2–5 years of low intensity fire (Birk 1979; Raison *et al.* 1983; Morrison *et al.* 1996). Kenny *et al.* (2004) suggested that potential conflicts between management strategies for fuel reduction and biodiversity conservation in these forests can be resolved through careful landscape level planning, as discussed in Conroy (1996), Morrison *et al.* (1996), Bradstock *et al.* (1998) and Bradstock and Gill (2001).

1.2.7.2. Backwater grevillea (*Grevillea scortechinii* subsp. *sarmentosa*)

While general fire interval guidelines have been developed based on broad vegetation groupings (Kenny *et al.* 2004), sometimes trade-offs must be made in the case where some species are ‘winners’ and others are ‘losers’ as a result of fire management practices (Moretti

et al. 2004; Duff *et al.* 2013; Moritz *et al.* 2014; Cardoso *et al.* 2016). Often the potential impact of fire on populations of threatened species is prioritised as a critical element in decision making for ecologically sustainable fire management (Richards *et al.* 1999; Legge *et al.* 2015; Connell *et al.* 2019). For the purposes of this research, the Banbai Aboriginal rangers selected the threatened plant species, Backwater grevillea (*Grevillea scortechinii* subsp. *sarmentosa*) as a case study in order to learn about the impact of cultural burning on this plant. The intention of the research was to study the changes brought about by cultural burning and to use this information to guide the rangers' adaptive management of Wattleridge Indigenous Protected Area for the conservation of biocultural diversity.

Wattleridge IPA, located on Banbai Country in the New England Tablelands of NSW, has high levels of biodiversity and cultural values (Banbai Business Enterprises Inc. 2014), and contains a large proportion of the range of the Backwater grevillea (Department of Planning Industry and Environment 2020a). The Banbai rangers were not aware of any Indigenous traditional uses or cultural values for this plant, but were motivated to conserve the grevillea as much of its population exists on their Country (McKemey *et al.* in press). The Backwater grevillea is a low spreading shrub that occurs in dry sclerophyll forest, with a scattered distribution restricted to granite soils of the New England Tablelands (Threatened Species Scientific Committee 2013). Hunter (2003b) found the Backwater grevillea to be locally very common at Wattleridge IPA and the Backwater area, estimating that there were probably greater than 10,000 individuals, possibly as many as 20,000.

The Backwater grevillea is listed as Vulnerable in NSW under the BC Act (Department of Planning Industry and Environment 2020a). The subspecies is largely an obligate seeder and regenerates from seed following fire (Hunter 2003b). Fire management recommendations for the Backwater grevillea were 'no fire more than once every 11 years' (Hotspots Fire Project 2016). The main identified threats to Backwater grevillea are cattle grazing; vegetation clearing for pasture; roadworks; inappropriate fire regimes; weed invasion, particularly *Rubus fruticosus* (blackberry); and disturbance from feral animals, especially *Sus scrofa* (feral pigs) (Minister for the Environment 2008). Hunter (2003b) described the main threats as 'a fire regime that is more frequent than every 8 years and possibly also pig damage'. Due to the small size of Backwater grevillea populations, there is a risk of local extinctions resulting from these threats (Minister for the Environment 2008). The Conservation Advice for the Backwater grevillea identified the following research priorities: an assessment of this species' response to fire; and, to more precisely assess total population size, distribution, ecological

requirements and the relative impacts of threatening processes (Minister for the Environment 2008).

1.2.7.3. Short-beaked echidna (*Tachyglossus aculeatus*)

Monotremes are a group of egg-laying mammals, displaying a mosaic of ancestral and derived anatomical features (Sprent 2012; Regnault *et al.* 2020). Due to their unique features, there has been much interest in monotremes from phylogenetic, morphological, behavioural and ecological perspectives (Smith *et al.* 1989; Abensperg-Traun 1991; Abensperg-Traun *et al.* 1991; Abensperg-Traun and De Boer 1992; Augee 1992; Green *et al.* 1992; Abensperg-Traun 1994; Rismiller and McKelvey 2000; Nicol *et al.* 2011; Griffiths 2012; Nicol and Morrow 2012; Hogan and Morrow 2015; Klieve *et al.* 2015; Regnault *et al.* 2020; Smales *et al.* 2020). The short-beaked echidna ('echidna') is one of only five extant species of monotreme and is the most widespread native mammal in Australia, occupying divergent habitats from the tropics to the arid centre (Augee *et al.* 2006). The echidna also has widespread cultural value and is a favoured traditional food to many of the Indigenous peoples of Australia (Cubis 1977; McBryde 1978; Foley 2005; Australian Museum Business Services 2013; Martin 2014; Daniels *et al.* 2018; Roberts *et al.* 2018; Sonter 2018).

The echidna is a solitary, medium-sized mammal, with a diet primarily consisting of ants, termites and invertebrates (Smith *et al.* 1989) and a highly seasonal life history (Sprent 2012). Their food is generally widespread and abundant, so echidna habitat use and selection is primarily constrained by availability of shelter and secondarily by food (Smith *et al.* 1989). The echidna is equipped with protective spines and has few predators other than the native dingo (*Canis dingo*) and invasive mesopredator, the red fox (*Vulpes vulpes*), predation from which increases following fire (Hradsky *et al.* 2017). Echidnas have adapted to living in fire-prone environments through their ability to use energy-conserving torpor to facilitate survival in a fire-scorched landscape (Nowack *et al.* 2016). Through this research, we demonstrate that the echidna is a cultural keystone species to the Banbai people, and undertake cross-cultural monitoring at Wattleridge IPA to assess the impact of cultural burning on the echidna.

1.2.8. Wildfire management

Prescribed fire is widely accepted as a conservation tool because fire is essential to the maintenance of native biodiversity in many terrestrial communities, such as in North and

South America, Australia, Africa and Mediterranean Europe (Freeman *et al.* 2017). The intentional use of fire to conserve fire-prone ecological communities, is generally viewed as an ecologically and economically beneficial practice by scientists, policy makers and managers. The practice is thought to maintain manageable fuel loads that decrease the risks and economic costs of wildfire while restoring or conserving native biota. To best achieve conservation goals, researchers should seek to understand contemporary fire–biota interactions across trophic levels, functional groups, spatial and temporal scales, and management contexts (Freeman *et al.* 2017).

Prescribed burning in Australia is commonly used, but controversial (Moritz *et al.* 2014). An increased likelihood of extreme fire weather and longer fire seasons (Bureau of Meteorology and CSIRO 2020) is driving increased pressure to manage fire through prescribed burning (Gill 2012). Fuel reduction burning can partially reduce risk to human life and economic assets, although trade-offs with risks to environmental assets such as biodiversity and ecosystem services are not well understood (Moritz *et al.* 2014; Hunter and Robles 2020). An over-arching research challenge is to define ecologically appropriate fire regimes for diverse ecosystems in different ecological, economic and geographical contexts while identifying the need for particular shapes, sizes and spatial arrangements of burned areas (Gill *et al.* 1999). Functional responses of species to fire frequencies, sizes, timings and intensities provide a measurable basis for predicting how ecological diversity will respond to management and climate change (Moritz *et al.* 2014). However, some academics contest that more than 60 years of concentrated empirical scientific research on the efficacy of prescribed burning has not ended the scientific debate about even basic relationships between fuels and fire behaviour and their effectiveness for wildfire management (Neale *et al.* 2020a). In their review of prescribed burning in Australia, Penman *et al.* (2011) found that: (1) prescribed burning can achieve a reduction in the extent of wildfires, but, at the required level, the result is an overall increase in the total area of the landscape burnt; (2) fuel reduction has less influence than weather on the extent of unplanned fire; (3) it is important to incorporate ecological values into prescribed burning programmes, and (4) an adaptive risk management framework combined with enhanced partnerships between scientists and fire-management agencies is necessary to ensure that ecological and fuel reduction objectives are achieved. Morgan *et al.* (2020) recommended a more comprehensive deployment of prescribed burning (rather than focusing resources on wildfire suppression) in southeast Australia to mitigate increasing risks to human lives, property, biodiversity and the environment associated with

wildfire due to climate change. Governments, such as in NSW, attempt to translate research into policy to guide fire management, such as *Living with Fire in NSW National Parks* (Office of Environment and Heritage 2013).

Following the ‘Black Summer’ fires in 2020, the Australian Government launched a Royal Commission into National Natural Disaster Arrangements (‘Bushfires Royal Commission’) while state governments in southeast Australia initiated various bushfire inquiries. Since 1939, more than 50 public inquiries, reviews and royal commissions have been held into matters concerning the management of fire in landscapes, including prescribed burning (Morgan *et al.* 2020). Of the seven matters identified for inquiry through the Bushfires Royal Commission, an entire matter was devoted to ‘any ways in which the traditional land and fire management practices of Indigenous Australians could improve Australia’s resilience to natural disasters’ (Royal Commission into National Natural Disaster Arrangements 2020). This is in contrast to past bushfire inquiries, most of which have ignored the experiences, concerns, rights and interests of Indigenous peoples (Williamson *et al.* 2020). Some past bushfire inquiries have considered Indigenous fire management. However, they concluded that there was very limited scientific information available to inform its effectiveness for bushfire management, or focused on past Indigenous burning practices while overlooking the opportunities that exist today (Esplin *et al.* 2003; Environment and Planning Committee 2017; Neale *et al.* 2020). Williamson *et al.* (2020) suggested that the most urgent forum where Indigenous people must have a strong presence is in the context of post-disaster inquiries and commissions, including any co-design of new policies and programs created in response to the disasters. To avoid duplication of findings of previous bushfire inquiries and widen the scope of our understanding of Indigenous fire management, Neale *et al.* (2020) recommended that the Commonwealth Government create a funding stream specifically to develop Indigenous-led, long-term research projects. Such projects could support new and existing Indigenous fire management initiatives in southern Australia, and examine the social, economic and ecological benefits of these initiatives.

Chapter 2 discusses existing knowledge and identifies research gaps through a literature review of contemporary cultural burning in southeast Australia. This thesis, one of the first of its kind to develop cross-cultural collaboration to support the renewal of cultural burning in southeast Australia, provides an initial attempt to build such a research project as recommended by Neale *et al.* (2020a) and the 2020 Bushfires Royal Commission.

1.3. Research aims and objectives

This thesis aims to explore the question: how can Indigenous rangers and Western scientists work together to co-produce cross-cultural knowledge ('right way' science) to support and provide documented evidence for the benefits and challenges of Indigenous cultural fire management? I aim to provide case studies of ethical, productive and mutually beneficial research partnerships with the Banbai and Yugul Mangi peoples, and provide an opportunity for them to share their biocultural knowledge related to fire, seasons and Country. Together, the Banbai rangers and I aspired to share the story of cultural fire renewal undertaken by their community in a post-colonial nation-state where fire management has been altered since European settlement. Furthermore, the research aims to generate quantitative and qualitative evidence to consider the impacts of cultural burning on ecological and cultural values.

Therefore, the specific objectives of this thesis are:

1. To describe the current status of contemporary Indigenous cultural fire management in southeast Australia;
2. To provide case studies of Indigenous cultural fire management for the Yugul Mangi people at SEAL IPA (NT) and Banbai people at Wattleridge IPA (NSW). To consider how Indigenous biocultural knowledge and various other knowledges (archaeological, ethnohistorical, ecological, cross-cultural and local) can be used to inform contemporary cultural fire management, for example, through the co-development of fire and seasons calendars intended to guide cultural burning;
3. To use cross-cultural methods to assess how the culturally significant echidna and threatened Backwater grevillea respond to cultural burning;
4. To compare the effects of, and fuel hazard changes associated with, various fire management treatments. These include: Aboriginal cultural burning, a National Park and Wildlife Service NSW (NPWS) hazard reduction burn, and a severe wildfire;
5. To compare the impact of a cultural burn with a hazard reduction burn on dry sclerophyll forest vegetation composition, cover, abundance and species richness;
6. To synthesise the findings of our research to: assess the outcomes of cultural burning in relation to its stated benefits; demonstrate how cross-cultural knowledge can support Indigenous cultural fire management and biodiversity conservation; and consider the broader benefits and potential applications of collaborative cross-cultural approaches.

1.4. Outline of the thesis

Following this introductory chapter, I address my thesis aims in seven chapters (Chapters 2–7), which have been prepared as a series of papers for publication. As a consequence of the ‘thesis by publication’ approach, there is some repetition in the introduction, methods and references of each chapter. Because each chapter has been prepared as a paper, discussions are incorporated throughout the thesis at the end of each chapter/paper. I conclude my thesis with Chapter 8, which provides a summary and synthesis of key findings, describes my contribution to current theoretical and practical knowledge, outlines the limitations of the research, and provides recommendations for future research.

Research aims and objectives are addressed as per below:

Objective 1: To describe the current status of Indigenous cultural fire management in southeast Australia

This objective is addressed in Chapter 2, where I review academic and grey literature to determine the current status of Indigenous cultural fire management in southeast Australia. This chapter has been published online as a preprint and will be submitted for publication in a peer-reviewed scientific journal:

McKemey, M. B., Costello, O., Ridges, M., Ens, E. J., Hunter, J. T., & Reid, N. C. H. (2020). A review of contemporary Indigenous cultural fire management literature in southeast Australia. *EcoEvoRxiv*. doi:10.32942/osf.io/fvswy

Objective 2: To provide case studies of Indigenous cultural fire management for the Yugul Mangi people at SEAL IPA (NT) and Banbai people at Wattleridge IPA (NSW). To consider how Indigenous biocultural knowledge and various other knowledges (archaeological, ethnohistorical, ecological, cross-cultural and local) can be used to inform contemporary cultural fire management, for example, through the co-development of fire and seasons calendars intended to guide cultural burning

This objective is addressed in Chapter 3, where I investigate the use of cross-cultural knowledge for fire management through the development of a fire and seasons calendar for South East Arnhem Land IPA, and has been published as the following paper:

McKemey, M., Ens, E., Yugul Mangi Rangers, Costello, O., & Reid, N. (2020). Indigenous Knowledge and Seasonal Calendar Inform Adaptive Savanna Burning in Northern Australia. *Sustainability*, 12(3), 995.

This objective is also addressed in Chapter 6, where I investigate the use of various knowledges for the co-production of a fire and seasons calendar for Wattleridge IPA, and has been published in the journal, *Austral Ecology*:

McKemey, M., Banbai Rangers, Ens, E., Hunter, J., Ridges, M., Costello, O., & Reid, N. (2021). Co-producing a fire and seasons calendar to support renewed Indigenous cultural fire management. *Austral Ecology*. <https://doi.org/10.1111/aec.13034>

Objective 3: To use cross-cultural methods to assess how the culturally significant echidna and threatened Backwater grevillea respond to cultural burning

This objective is addressed in Chapter 4, where we describe the process of reintroducing cultural burning into a long unburnt ecosystem in southeast Australia. Through cross-cultural monitoring with the Banbai Aboriginal rangers, we assess the impact of cultural burning on a cultural keystone species, the short-beaked echidna (*Tachyglossus aculeatus*). The chapter has been published as the following paper:

McKemey, M. B., Patterson, M., Banbai Rangers, Ens, E. J., Reid, N. C. H., Hunter, J. T., Costello, O., Ridges, M., & Miller, C. (2019). Cross-Cultural Monitoring of a Cultural Keystone Species Informs Revival of Indigenous Burning of Country in South-Eastern Australia. *Human Ecology* 47(6): 893-904. doi:10.1007/s10745-019-00120-9

In Chapter 5, we consider the impacts of cultural burning on the Backwater grevillea (*Grevillea scortechinii* subsp. *sarmentosa*) and the adoption of this threatened plant species into a cultural management framework. This chapter has been prepared for publication as the following paper, and has been submitted to the journal, *International Journal of Wildland Fire*:

McKemey, M., Rangers, B., Patterson, M., Hunter, J. T., Ridges, M., Ens, E., Miller, C., Costello, O., & Reid, N. C. H. (in press). Indigenous cultural burning had less impact than wildfire on the threatened Backwater grevillea (*Grevillea scortechinii*

subsp. *sarmentosa*) while effectively decreasing fuel loads. *International Journal of Wildland Fire*

Objective 4: To compare the effects of, and fuel hazard changes associated with, various fire management treatments. These include: Aboriginal cultural burning, a National Park and Wildlife Service NSW (NPWS) hazard reduction burn and a wildfire;

Also in Chapter 5, we compare the effects of, and fuel hazard changes associated with, Aboriginal cultural burning, a National Park and Wildlife Service NSW (NPWS) hazard reduction burn, and a wildfire. Throughout Chapters 2, 3, 4, 5 and 6, Indigenous rangers explain the characteristics of cultural burning, and how it contrasts with hazard reduction burning and wildfire. In Chapter 5, we provide a quantitative assessment of various fire effects and discuss how Western and Indigenous sciences describe various fire treatments.

Objective 5: To compare the impact of a cultural burn with a hazard reduction burn on dry sclerophyll forest vegetation composition, cover, abundance and species richness;

In Chapter 7, we investigate the impact of cultural burning on dry sclerophyll forest composition, cover, abundance and species richness. This chapter is entitled ‘Impacts of Indigenous cultural burning versus hazard reduction on dry sclerophyll forest composition, abundance and species richness in southeast Australia’ and will be submitted to a journal for publication.

Objective 6: To synthesise the findings of our research to: assess the outcomes of cultural burning in relation to its stated benefits; demonstrate how cross-cultural knowledge can support Indigenous cultural fire management and biodiversity conservation; and consider the broader benefits and potential applications of collaborative cross-cultural approaches.

This objective is addressed in the concluding Chapter 8, where I synthesise the findings of my research, place it in the context of other research and discuss potential applications of the findings.

Chapter 2. A review of contemporary Indigenous cultural fire management literature in southeast Australia

Title of Article:

‘A review of contemporary Indigenous cultural fire management literature in southeast Australia’

Authors: Michelle B. McKemey, Oliver Costello, Malcolm Ridges, Emilie J. Ens, John T. Hunter and Nick C. H. Reid

Manuscript published online as a pre-print:

McKemey, M. B., Costello, O., Ridges, M., Ens, E. J., Hunter, J. T., & Reid, N. C. H. (2020). A review of contemporary Indigenous cultural fire management literature in southeast Australia. *EcoEvoRxiv*. doi:10.32942/osf.io/fvswy <https://ecoevorxiv.org/fvswy/>

2.0. Abstract

Indigenous cultural fire management is being recognised and revived in Australia and other parts of the world. To explore the benefits of contemporary cultural fire management in southeast Australia and barriers to its revival, we undertook a systematic analysis of the literature. Seventy documented applications of cultural fire management projects were found with the potential for significant upscaling. Over the last decade, eight policies related to Indigenous fire management have been developed by state and territory governments in southeast Australia, with varying levels of implementation. Seventy-eight benefits and 22 barriers were identified in relation to cultural fire management. In the cases where cultural fire management has been successfully reinstated as an ongoing practice, Indigenous leadership, extraordinary relationships, strong agreements and transformational change were identified as drivers of success. For cultural fire management to grow, more funding, policy implementation, long-term commitment, Indigenous control and decision making, mentoring, training and research are required. Several areas of research could facilitate the expansion of cultural fire management and be applied in similar contexts globally, including the Americas and Africa. While Indigenous voices are increasingly represented in the literature, it is imperative that mutually beneficial and respectful partnerships are developed in the cross-cultural interface of landscape fire management.

Key words: Fire management, cultural burning, cultural fire, wildfire, bushfire, Indigenous knowledge.

2.1. Introduction

According to Indigenous Lore, Aboriginal people have lived on their ancestral clan estates ('Country') throughout Australia since the Dreamtime (Dean 1996; Behrendt 2016). Western science has recorded evidence of at least 65,000 years of Aboriginal occupation of Australia (Clarkson *et al.* 2017; McNiven *et al.* 2018). In 1788, Australia was colonised by the British, causing widespread social, cultural, political and environmental disruption, dispossession and denial of rights and recognition for Indigenous people (Rolls 1981; Blomfield 1992; Langton 1999; Harris 2003). The lack of acknowledgement of Indigenous Australian stewardship of the environment was part of the legal justification of *terra nullius* by the British government and the colonial legislatures (Bardsley *et al.* 2019). While the legacy of these injustices prevail in post-colonial Australian society (Department of the Prime Minister and Cabinet 2020), in some areas decolonising processes are being activated and driving an increasing appreciation and reinstatement of Indigenous practices of caring for Country (Baker *et al.* 2001; Hill 2003; Altman and Kerins 2012; Spurway 2018; Neale *et al.* 2019a; Weir and Freeman 2019; Weir *et al.* 2020). Indigenous fire practitioners in northern Australia are considered by some to be world leaders in savanna fire management, due to their landscape-scale, Indigenous-led, fire management programs (Lipsett-Moore *et al.* 2018; Moura *et al.* 2019; Dann and Woodward 2020). Savanna burning provides an opportunity for Indigenous Traditional Owners and rangers to use Indigenous knowledge, practice and governance systems to apply fire management on their Country (Russell-Smith *et al.* 2009). This has resulted in social, cultural, environmental and economic benefits for Indigenous landowners (Jackson *et al.* 2017; Northern Land Council 2017; Ansell and Evans 2019) although some biodiversity and social benefits are debated (Dockery 2010; Martin 2013; Fache and Moizo 2015; Petty *et al.* 2015; Perry *et al.* 2018; Corey *et al.* 2019; Evans and Russell-Smith 2020).

Indigenous burning practices over thousands of years have shaped extant landscapes and vegetation (Bowman 1998; Enright and Thomas 2008; Gammage 2011; Fletcher *et al.* 2021). Early literature of Indigenous fire management was dominated by Western perspectives and characterised by debates around 'firestick farming' by non-Indigenous academics (mostly anthropologists and archaeologists) such as Jones (1969), King (1963), Hallam (1975), Horton (1982) and Kohen (1996). This debate was supplemented by studies on the palaeoecology of fire in Australia (Singh *et al.* 1981; Pyne 1991). From the 1990s, Indigenous authorship emerged, such as in Russell-Smith *et al.* (1997), (Langton 1999), Yibarbuk *et al.* (2001) and Lehman (2001) as the literature around Indigenous fire

management grew (Bowman 1998; Gott 1999; Gott 2002; Bowman 2003b; Enright and Thomas 2008; Russell-Smith *et al.* 2009; Gammage 2011). Particularly in the last decade, several Indigenous voices have come to the forefront of the literature related to cultural fire management (Robinson *et al.* 2016; Spurway 2018) in McGregor *et al.* (2010), Fitzsimons *et al.* (2012), Pascoe (2014), Zander *et al.* (2014) Prober *et al.* (2016), Maclean *et al.* (2018), Neale *et al.* (2019a), Darug Ngurra *et al.* (2019), Weir and Freeman (2019), McKemey *et al.* (2019b), McKemey *et al.* (2020a), Fletcher *et al.* (2021), Bourke *et al.* (2020) and Steffensen (2020).

Despite the impacts of colonisation (Elder 2003) and seemingly overwhelming socio-political and environmental challenges (Spurway 2018), Indigenous cultural burning practices are being revived in southeast Australia. The unprecedented ‘Black Summer’ bushfires of 2019–20 in southeast Australia burnt almost 19 million ha, destroyed over 3,000 homes and killed 33 people (Filkov *et al.* 2020; Nolan *et al.* 2020; Wintle *et al.* 2020). This resulted in public questioning of existing wildfire management strategies and discussion about alternatives, such as cultural fire management (Firesticks Alliance 2020). In light of increasing public interest in Indigenous cultural fire management and the Indigenous community-driven revival of cultural burning as an applied practice, analysis of the existing information can inform ongoing research and development of contemporary cultural fire management in southeast Australia. This paper aims to review, summarise and evaluate literature related to contemporary Indigenous cultural fire management in southeast Australia (Harvard University 2020). We aim to provide an overview of the current status of cultural burning in southeast Australia and identify key themes, issues and research gaps. Finally, we aim to provide recommendations to enhance research and practice related to cultural fire management.



Image 2-1 Ranger Jimmy Daly lighting a cultural burn at The Willows Boorabee IPA
(photo: David Milledge)

Box 2.1: What is cultural burning?

Dave Wandin of Wurundjeri Nation, Victoria, explained ‘Aboriginals look after their Country, because their Country has looked after them. The Country gave them tools, food, clothing, medicine and shelter. Aboriginal people want to protect the land and keep it safe and strong ... The land is sacred to Aboriginal people; it is their job to take care of the land ... If we learn how to care for the Country it will be happy again ... It is really important that Aboriginal people bring back the firestick to look after the land’ (Schoof *et al.* 2018).

Shaun Hooper (2019) of Wiradjuri Nation, NSW, explained how Aboriginal people have a responsibility to care for Country: ‘This is demonstrated by Aboriginal peoples’ continued insistence that they must do cultural burning, it is the cultural expression of knowing who they are and what their responsibilities are in the cosmos. It is Aboriginal people maintaining their cultural practice, maintaining their Lore.’

The Firesticks Alliance Indigenous Corporation, which brings together many Aboriginal communities engaged in cultural burning in southeast Australia, used the term cultural burning to describe ‘burning practices developed by Aboriginal people to enhance the health of the land and its people. Cultural burning can include burning or prevention of burning for the health of particular plants and animals ... or biodiversity in general. It may involve patch burning to create different fire intervals across the landscape or it could be used for fuel and hazard reduction. Fire may be used to gain better access to Country, to clean up important pathways, maintain cultural responsibilities and as part of culture heritage management’ (Firesticks Alliance Indigenous Corporation 2019).

Darug Ngurra *et al.* (2019) explained that ‘cultural burns are slow moving, physically contained fires which are gentle and generative. Cultural burns have the health of Country as their key motivator’, and ‘Fire is critical to the health of Darug Country. It provides emotional and physical sustenance; it regenerates seeds, it shapes invasive plant lives, and it imparts vibrant teachings on the humans who co-create it.’

From the perspective of Indigenous people, knowledge about landscape burning is not only about where, when and how to burn; it is also about ensuring that those who light fires are acting under the appropriate authority of the people of that Country—that is, people who have the residential and kinship ties that underpin customary connections. For Indigenous people, this is often the single most critical element of fire management (Robinson *et al.* 2016).

Cultural burning is a practice that supports Country. Different people have different considerations about how cultural burns are, or might be, practised, including the involvement of non-Indigenous people and Aboriginal people who are not traditional custodians. The distinct leadership and agenda setting role of traditional custodians as the people of Country who speak for Country is often spoken about as paramount, but not always (Weir and Freeman 2019).

Caring for Country is a broader way of managing and viewing the natural world, it is not just about surviving and providing for family and clan by protecting the land, animals and vegetation in order to maximise peoples’ benefits from hunting, fishing and foraging. It is also not just about protecting Country and livelihoods from destructive natural events such as large-scale bushfires. It is all this and more: caring for Country is an end in itself; natural disaster mitigation and livelihoods protection are simply elements of it within an overarching holistic cosmology (Spurway 2018).

2.2. Methods

2.2.1. Authors

The authors of this paper include Oliver Costello (a Bundjalung Aboriginal man), co-founding Director of the Firesticks Alliance, and five authors who are non-Indigenous academics/professionals (ecologists and a cultural scientist), most of whom have worked with Indigenous people for many years.

2.2.2. Definitions

In this paper, the terms ‘Aboriginal’ and ‘Indigenous’ are used to describe the First Nations peoples of Australia. We use the term ‘cultural burning’ to describe the application of fire by Aboriginal peoples and ‘cultural fire management’ to encompass the broader cultural practices, values, heritage and land management activities that relate to Indigenous use of fire. Cultural fire management can also include the prevention and exclusion of fire. These terms are commonly used in eastern and southern Australia. There are many views of the definition of cultural burning and fire management, which can include perspectives related to cultural responsibility, Lore, history of practice, fire behaviour, roles, caring for Country and holistic land management (see Box 2.1: *What is cultural burning?*). In other areas of Australia and globally, various terms are used to describe Indigenous fire management and its application, such as Aboriginal or traditional fire management, Aboriginal or Indigenous burning, Indigenous wildfire management, cultural fire and burning of Country. Both the terms ‘bushfire’ and ‘wildfire’ are used to describe an unplanned, vegetation fire (Rural and Land Management Group 2012). We define southeast Australia as NSW, ACT, Victoria, South Australia, Tasmania and southern Queensland (spanning the sub-tropic, temperate and grassland climatic zones; Bureau of Meteorology 2001).

2.2.3. Scope

We limited our focus to the contemporary literature of the last 20 years (2000–2020). Inferences regarding Indigenous agency in the fire history of southeast Australia, as interpreted from environmental history, are beyond the scope of this paper.

2.2.4. Searches and Sources

The academic literature (peer-reviewed papers published in academic books or journals) relevant to contemporary cultural fire management in southeast Australia was searched by using keywords ('cultural burning', 'Indigenous fire', 'Aboriginal fire'), themes and regions in databases (Scopus and Google Scholar) and bibliographies of relevant papers.

The results for academic literature were limited, so we expanded our search to grey literature in order to capture a broader range of documents and increase the rigour of the literature review (Haddaway *et al.* 2020). The results for grey literature included government reports, non-government organisation (NGO) documents, conference proceedings, non-academic books and journals. Using internet searches and email correspondence we identified government policies related to contemporary cultural fire management in southeast Australia.

We also used multimedia sources to capture the breadth of documented information by Indigenous and non-Indigenous authors from multi-disciplinary perspectives (Mahood *et al.* 2014). These sources included media articles, podcasts, websites, posters and unpublished documents, and were used to provide additional information, such as case studies of cultural burning.

2.2.5. Analysis

The main findings were summarised from key academic and grey literature from sources that were relevant, current and authoritative (QUT 2020). Information from academic, grey and multimedia sources was collated to provide an overview of case studies of contemporary cultural fire management projects including details (where available) of: place, Aboriginal group, land tenure type, land area and description of project. Government policy documents were analysed to provide an overview of relevant state, territory and federal government policies related to Indigenous fire management. From the academic and grey literature, we identified and summarised the key issues of: benefits of, and barriers to, cultural fire management. Where benefits and barriers were described in the literature, these were coded and categorised (Saldaña 2015; Onwuegbuzie *et al.* 2016). The benefit categories of Indigenous cultural fire management developed by Maclean *et al.* (2018) were adopted. The key themes (Appendix 2.1) of open access media reporting on cultural burning were investigated, prior to and during the Black Summer bushfires (Box 2.2). All of this

information was synthesised in order to identify research gaps and provide recommendations for future research and practice (Jesson and Lacey 2006; Harvard University 2020).

2.3. Results

2.3.1. Summary of key literature

The literature search found 21 key articles related to contemporary Indigenous cultural burning in southeast Australia, the main findings of which are summarised in Table 2.1. Most of the articles were published from 2018 onwards, with only 5 published prior to this. The majority of articles discussed the benefits associated with Indigenous fire management, particularly environmental, social and cultural benefits. Many articles also described the impact of colonisation on cultural fire management, Indigenous rights, and engagements between Indigenous and non-Indigenous groups. Many of the papers provided a background to Indigenous burning, discussed people's relationship with fire and cultural burning as a strategy for wildfire management. Several of the articles mentioned barriers to cultural burning, such as lack of resources or power for Indigenous peoples.

Interestingly, the *Report of the Inquiry into the 2002-2003 Victorian Bushfires* (Esplin *et al.* 2003) concluded that Aboriginal cultural fire management knowledge and practice had been 'lost' or fragmented. In contrast, the 2020 bushfire inquiries found that engagement and application of Aboriginal cultural fire and land management should increase (Binskin *et al.* 2020; Owens and O'Kane 2020). As the benefits and barriers to cultural fire management are key issues to its implementation, we interrogated these issues further (Sections 2.3.4 and 2.3.5).

Box 2.2: Media coverage of cultural burning

Media interest in cultural burning intensified during the Black Summer bushfires of 2019-20, with 60 articles published on open access media in the first two months of 2020. Prior to the bushfire crisis, media attention focused on issues related to partnerships between Indigenous groups, government organisations, NGOs and others; and discussed the revival or reintroduction of cultural fire management.

During the bushfire crisis, the main focus shifted to the: potential for cultural fire management to improve how fire is managed; destruction caused by bushfires (lives, wildlife/vegetation, homes, infrastructure, general, cultural heritage, trauma/grief); and potential causes of bushfires (climate change, mismanagement, fuel loads).

The media focused on some common themes both before and during the Black Summer bushfire crisis, such as: the potential benefits of cultural fire management (environmental, cultural, social and bushfire management); case studies of cultural fire management; providing background (historical context) to cultural fire management, and discussing cultural fire management as a strategy to manage bushfire.

Media coverage of cultural burning had both similarities and differences to the literature. For example, both media and the literature focussed on: providing a background to Indigenous burning; the cultural and environmental benefits of cultural fire management; examples of the practice of cultural burning; and cultural burning as a management strategy. Beyond this, the literature in southeast Australia mainly focussed on: Indigenous rights; respect between Indigenous and non-Indigenous groups; working together; the impacts of colonisation on cultural fire management; and the social benefits of cultural fire management. Other prevalent themes in the media were: the potential for cultural fire management to improve how fire is managed; and to reduce the risk of bushfire.

Particularly during the Black Summer bushfire crisis, the media focussed on the causes (blame) and destruction rendered by bushfires. In contrast, academic papers focussed on issues such as identifying research gaps and priorities, and the lack of recognition of Indigenous knowledge. Therefore, the media generally sought to find answers for the causes of the bushfires, while potentially proposing cultural fire management as a panacea to reduce bushfire risk in future. The research articles were more considered and careful in their recommendations regarding cultural fire management (Table 2.1).

Table 2-1 Summary of main findings of key literature relevant to contemporary cultural fire management in southeast Australia.

Paper title	Relevant location	Main findings	Reference
<i>Turning Back the Clock: Fire, Biodiversity and Indigenous Community Development in Tasmania</i>	Tasmania	Discussed pre-colonial Aboriginal burning in Tasmania. Described a case to reintroduce cultural burning into the Tasmanian Wilderness World Heritage Area and trial burns that had been undertaken.	Lehman (2001)
<i>Frameworks to support Indigenous managers: the key to fire futures</i>	Australia-wide	Discussed the shifting paradigms in land and fire management, from the dominant paradigm of the colonial era to a more inclusive paradigm where partnerships between rural communities, government managers, NGO staff, Indigenous peoples and scientists were emerging. The key challenge for researchers and policy makers was in developing new frameworks (legislation, regulation, governance, financial and career support) that enable Indigenous people into a policy-making role that fully respects their rights. Use of dual (Indigenous and non-Indigenous) toolbox for land management.	Hill (2003)
<i>Australia burning: fire ecology, policy and management issues</i>	Australia-wide	Australia cannot be 'fire-proofed' but by using Indigenous fire management as a guide, the impacts of fire may be reduced- although wildfires will not be prevented. Approaches to fire management developed over many millennia by Indigenous Australians must be a major area of future research and associated policy development. Described the importance of Western and Indigenous science systems working together in a respectful way.	Cary <i>et al.</i> (2003)
<i>Report of the Inquiry into the 2002-2003 Victorian Bushfires</i>	Victoria	Chapter 12: Traditional Burning Practices of Aboriginal People and the Prescribed Burning Debate in Victoria. Considered the notion that contemporary prescribed burning should replicate pre-colonial Aboriginal burning. After reviewing the evidence, the Inquiry concluded that not enough is known about traditional burning in southern Australia to be able to re-create an Aboriginal burning regime. Knowledge has been lost, or is fragmentary, and any use of a 'traditional Aboriginal burning regime' in southern Australia would be an experiment in land management and should be recognised as such.	Esplin <i>et al.</i> (2003)
<i>The Retention, Revival, and Subjugation of Indigenous Fire Knowledge through Agency Fire Fighting in Eastern Australia and California</i>	New South Wales & Queensland	Explored the potential impact of training and employment with wildfire management agencies on the retention of Indigenous fire knowledge. The paper focused on the comparative knowledge and experiences of Indigenous Elders, cultural practitioners, and land stewards in connection with 'modern' political constructs of fire. This article emphasised the close link between cross-cultural acceptance, integration of Indigenous and agency fire cultures, and the ways in which knowledge types are shared or withheld. By highlighting how privilege intersects with ethnicity, class, gender and age, this article demonstrated how greater cross-cultural acceptance could aid ongoing debates on how to coexist with wildfire today. (It should be noted that the majority of this article focused on California and drew upon interviews with only two Indigenous Australians.)	Eriksen and Hankins (2014)

<i>Protocols for Indigenous fire management partnerships</i>	Australia-wide	The review distilled key lessons learned from the incorporation and translation of Indigenous knowledge into a range of fire management activities and programs and charted the key methods, processes and protocols for incorporating Indigenous knowledge into environmental management, including fire management. The report described a number of protocols for Indigenous fire management partnerships for application nation-wide and identified research priorities.	Robinson <i>et al.</i> (2016)
<i>A national framework to report on the benefits of Indigenous cultural fire management</i>	Australia-wide	This report built on the efforts of a range of Indigenous fire related activities and partnerships across Australia that supported Indigenous groups and enterprises to maintain, learn, build and apply cultural fire knowledge and practices. A number of government programs were developing ways to establish national monitoring and evaluation frameworks to assess the benefits and collate the evidence needed for continued government support for Indigenous cultural fire management activities. Reporting on these benefits between agencies and organisations supporting these efforts can offer vital evidence needed to enable Indigenous cultural fire management, to support enterprises and sustain partnerships. Several chapters of this report were written by Indigenous authors, describing their cultural fire management practices.	Maclean <i>et al.</i> (2018)
<i>Southeast Australia Aboriginal fire forum</i>	Southeast Australia	The Southeast Australia Aboriginal Fire Forum 2018 was a landmark event, bringing together Aboriginal and non-Indigenous peoples personally invested in expanding the use of cultural burning and supporting the authority of Aboriginal peoples in the management of wildfire in southeast Australia and across the Australian continent more generally. This report identified several key themes that emerged from across the forum: creating knowledge, sharing knowledge, everyone together, and making it genuine.	Smith <i>et al.</i> (2018)
<i>Critical reflections on Indigenous peoples' ecological knowledge and disaster risk management in Australia: A rapid evidence review</i>	Australia-wide, with examples from southeast Australia	This paper documented the findings of a rapid evidence review of Australian Indigenous peoples' knowledges and disaster risk management. The evidence base demonstrated the strength of Indigenous peoples' fine-grained and place-based worldviews that integrate natural resource management with strategies to sustain political economies of living off Country and the mitigation of extreme events such as disasters. This approach requires a broader purview than currently taken by disaster risk management in Australia and necessitates a robust understanding of Indigenous worldviews if emergency managers want to effectively engage with Indigenous communities.	Spurway (2018)
<i>The natural hazard sector's engagement with Indigenous peoples: a critical review of CANZUS countries</i>	CANZUS countries, with examples from southeast Australia	The article reviewed literature on the origins of engagements and key rationales informing natural hazard management agencies' interactions with Indigenous peoples. Incorporating critiques of settler colonialism relevant to the CANZUS context, this review aimed to support established, emerging, and future collaborative engagements by investigating and analysing the literature.	Thomassin <i>et al.</i> (2019)
<i>Walking together: a decolonising experiment in</i>	Victoria	Drawing upon a case study of collaborative wildfire management between Dja Dja Wurrung peoples and settler wildfire management agencies on Dja Dja Wurrung Country in Victoria, this article argued for an understanding of such collaborations as	Neale <i>et al.</i> (2019a)

<i>bushfire management on Dja Dja Wurrung Country</i>		'decolonising experiments'. This means paying attention to the open-ended character of collaborative initiatives, whether and how they materially improve the position of Indigenous peoples, as well as whether and how they give rise to new resources and strategies for the creation of other decolonising futures.	
<i>Indigenous people in the natural hazards management sector: Examining employment data</i>	Southern Australia	This study suggested that Indigenous peoples are statistically under-represented in the natural hazards management sector in southern Australia. Nonetheless, there are signs of increased Indigenous involvement within the natural hazard sector, particularly through collaborative fire management initiatives. The natural hazards management sector should prioritise supporting these engagements as part of their commitment to the resilience of Indigenous peoples and their communities.	Neale <i>et al.</i> (2019b)
<i>Cross-Cultural Monitoring of a Cultural Keystone Species Informs Revival of Indigenous Burning of Country in South-Eastern Australia</i>	NSW	This study described how the Banbai people reintroduced cultural burning at Wattleridge Indigenous Protected Area. Banbai Rangers and non-Indigenous scientists conducted cross-cultural research to investigate the impact of burning on a cultural keystone species, the short-beaked echidna (<i>Tachyglossus aculeatus</i>). The study described a cross-cultural research model whereby Indigenous rangers and non-Indigenous scientists worked together to inform adaptive natural and cultural resource management.	McKemey <i>et al.</i> (2019b)
<i>Yanama budyari gumada: reframing the urban to care as Darug Country in western Sydney</i>	NSW	This paper made explicit practices of caring, healing and rejuvenation at Yellomundee Regional Park, Darug Country in western Sydney, through focussing on the return of cultural burns. The Darug principle of yanama budyari gumada, to 'walk with good spirit', embodies and invites new ways of thinking and practising intercultural caring-as-Country in heavily colonised, urban places like Yellomundee. The documentation of the practices has far-reaching implications for NRM and planning, and the importance of geographies of care for unceded urban places.	Darug Ngurra <i>et al.</i> (2019)
<i>Seeking knowledge of traditional Indigenous burning practices to inform regional bushfire management</i>	SA	A transdisciplinary review of the current academic knowledge of Indigenous traditional fire management was presented for the Mt Lofty Ranges in South Australia. This review suggested that there is very little formalised, academic knowledge available that could be utilised to inform prescribed burning practices in the region. To learn from traditional Indigenous land management: (a) formal knowledge needs to be generated on past regional burning practices; and (b) understanding needs to be developed as to whether past burning practices could lead to effective hazard management and biodiversity outcomes within contemporary landscapes. Such an integration of Indigenous knowledge for effective environmental management will only be possible if the injustices of past exclusions of the importance of Indigenous biocultural practices are recognised.	Bardsley <i>et al.</i> (2019)

<i>Fire in the south: a cross continental exchange</i>	ACT	This report documented a trip undertaken across southern Western Australia to exchange knowledge from southeast Australia about cultural burning with traditional owners and fire authorities. Fundamentally, Aboriginal people talked about the importance of understanding fire differently, to reposition it as not just something to fear, but as central to the regeneration of life. At the same time, all were concerned about the growth in catastrophic wildfires, and this intensified the focus on anticipatory land management practices.	Weir and Freeman (2019)
<i>The Theory/Practice of Disaster Justice: Learning from Indigenous Peoples' Fire Management</i>	ACT	Discussed the implications of the fire management experiences of Aboriginal peoples and how this might inform and be informed by the theory/practice of Disaster Justice. The case studies demonstrate the amount of work that is involved for Aboriginal fire managers to navigate and negotiate fire regulation regimes that do not necessarily align with their own governance priorities or their territories. The normative focus of Disaster Justice, the spatial-temporal forces of natural hazards and the community of practice that is fire management are all important opportunities for reframing and redressing along more just lines between natures and peoples.	Weir <i>et al.</i> (2020)
<i>Putting Country back together: a conversation about collaboration and Aboriginal fire management</i>	Victoria	Edited transcript of a conversation between two Aboriginal fire practitioners and a non-Indigenous researcher. The speakers largely focused on the management of Country, or lands and waters, and how wildfires can play both generative and potentially harmful roles in the management of Country.	Bourke <i>et al.</i> (2020)
<i>Final Report of the NSW Bushfire Inquiry</i>	NSW	Section 4.4.3: Traditional Aboriginal land management. There have been widespread calls for Aboriginal cultural fire practices to be employed in hazard reduction. The Inquiry heard that cultural burning is one component of a broader practice of traditional land management and does not necessarily have fuel reduction as its primary objective. The Inquiry heard that cultural burning is about caring for Country and maintaining healthy and ecological diverse and productive landscapes. It is also about practising cultural traditions. It is important that this principle is used by government and that wider implementation of Aboriginal land management practices is by Aboriginal people, supported by government agencies. The report made two recommendations regarding Indigenous cultural burning: Recommendation 25: 'That government adopt the principle that cultural burning is one component of a broader practice of traditional Aboriginal land management and is an important cultural practice, not simply another technique of hazard reduction burning.' Recommendation 26: 'That, in order to increase the respectful, collaborative and effective use of Aboriginal land management practices in planning and preparing for bush fire, government commit to pursuing greater application of Aboriginal land management, including cultural burning, through a program ... working in partnership with Aboriginal communities. This should be accompanied by a program of evaluation alongside the scaled-up application of these techniques.'	Owens and O'Kane (2020)

<i>Royal Commission into National Natural Disaster Arrangements Report</i>	Southeast Australia	Chapter 18: Indigenous land and fire management. The report found that Indigenous land management aims to protect, maintain, heal and enhance healthy and ecologically diverse ecosystems, productive landscapes and other cultural values. It is not solely directed to hazard reduction. Today, Indigenous land management maintains its traditional and cultural importance, while also leveraging technologies such as helicopters and satellites. Public interest focuses mainly on Indigenous fire management practices, despite it being just one aspect of the broad and integrated approach of Indigenous land management. There is growing recognition of the value of Indigenous land and fire management practices as a way to mitigate the effects of wildfires. There may be opportunities to reinvigorate Indigenous land management practices in parts of southern Australia. The report made two recommendations regarding Indigenous cultural burning: Recommendation 18.1: 'Indigenous land and fire management and natural disaster resilience: Australian, state, territory and local governments should engage further with Traditional Owners to explore the relationship between Indigenous land and fire management and natural disaster resilience.' Recommendation 18.2: 'Indigenous land and fire management and public land management: Australian, state, territory and local governments should explore further opportunities to leverage Indigenous land and fire management insights, in the development, planning and execution of public land management activities.'	Binskin <i>et al.</i> (2020)
<i>Fire Country: how Indigenous fire management could help save Australia</i>	Australia, including examples in southeast Australia	An autobiographical book that described Steffensen's mentoring by traditional Indigenous fire Elders in north Queensland and the spread of renewed cultural fire management into southeast Australia. The book described cultural burning as an 'artisanal and fully integrated patchwork' (Fernandes 2020) and the holistic, annual cycle of burning Country. It compared Western with Indigenous systems of fire management and addressed ecosystem restoration through cultural burning. Steffensen described his vision for the future of cultural fire management following the devastation of the Black Summer bushfires, including the training of Indigenous fire practitioners and cooperation among all sectors of society, in order to deal with one of the 'biggest environmental challenges in modern human history'.	Steffensen (2020)

2.3.2. Practice of cultural fire management

The literature is beginning to document case studies of Indigenous groups renewing cultural fire management, however, this does not mean that cultural burning did not exist in the absence of its documentation (Hill *et al.* 2000). For example, stories are emerging of Indigenous people setting foot on Country and lighting fires for the first time since Europeans invaded (Kristoff *et al.* 2019). From 2014, Banbai people started to reintroduce cultural burns on Wattleridge Indigenous Protected Area in northern NSW (McKemey *et al.* 2019b). In 2014, the Darug people undertook the first cultural burns on their Country near Sydney, since the onset of colonisation (Darug Ngurra *et al.* 2019). In 2017, the Dja Dja Warrung ‘walked together’ with the Victorian Government to light some of the first Indigenous-led cultural burns on public lands in Victoria (Neale *et al.* 2019a). From the Bunya Mountains in southern Queensland to the midlands of Tasmania, a groundswell of Indigenous cultural fire management is spreading across contemporary landscapes. The literature and media illustrated that throughout southeast Australia there were many Indigenous communities who were practicing, re-initiating or showing an interest in cultural fire management on their Country (Table 2.2). This has also been evidenced by the amount of interest and large number of participants in the annual *National Indigenous Fire Workshops* (1,500+ participants) and *On Country Workshops* run by the Firesticks Alliance (Maclean *et al.* 2018; Standley 2019; Costello and Standley 2020).

Maclean *et al.* (2018) found that Indigenous people from southeast Australia are re-engaging with cultural fire management practices via diverse and innovative enterprises and partnerships. They reported that cultural fire management is carried out on a mix of land tenures, including Aboriginal land, Indigenous Protected Areas, the Conservation Estate (Government, NGOs), local council or Crown land and private property. The published literature documented 70 cultural burning case studies from the southeast Australia states (Table 2.2), including 42 projects in NSW, 18 projects in Victoria, 5 projects in Tasmania, 3 projects in Queensland and one project each for ACT and SA. Most of the documented case studies were on public and Aboriginal land, with few examples on private land. The authors are aware of many projects on private land in NSW but these have not been published, therefore cultural burning on private land may be under-represented in these results. Most of the projects described in the literature have been implemented in the last decade, except the account by Lehman (2001) of an attempt to reintroduce cultural burning in Tasmania.

Few publications quantified the area burnt through cultural burning, so it was difficult to estimate the total area managed through cultural burning in southeast Australia. The closest approximations are for Victoria and NSW. In Victoria, approximately 347 ha of land has been culturally burnt since 2017 (Neale pers. comm.). This equates to 0.002% of the total land area of the State of Victoria. In NSW, 42,927 ha of land has been managed to prepare for cultural burning since 2014, which equates to 0.054% of the total land area of the State of NSW. It should be noted that not all areas of these states are fire prone; however, the proportion of land that has been culturally burnt in the last decade is still very small.

Maclean *et al.* (2018) found that Indigenous cultural fire management was developed and conducted via a suite of partnerships including Indigenous peer to peer partnerships, Indigenous-government partnerships, Indigenous-scientist partnerships and knowledge exchanges. Four drivers of Indigenous fire management practice were described: caring for Country; regeneration and protection of native species and managing invasive weed species; fuel reduction to protect important places, species, infrastructure and neighbouring properties; and meaningful employment, related social and economic benefits and outcomes.



Image 2-2 Participants at the National Indigenous Fire Workshop 2019 from various organisations and agencies, participating in cultural burning

Table 2-2 Summary of case studies identified in the literature (Appendix 2.2 contains a more detailed table).

State & Land Tenure Type	Approximate total known land area (ha)	Place and people	References
NSW			
Public lands	18,960 ha Many burn areas undefined	Yellomundee Regional Park (Shaws Creek Aboriginal Place), Darug Aboriginal community; Henty (Riverina), Wiradjuri; Coastal Themeda Headlands Coffs Harbour, Gumbayngirr; Monaro Plains, Ngarigo traditional custodians; Arakwal National Park Byron Bay, Arakwal/Bundjalung Country; Dorrigo / New England escarpment, Gumbayngirr; Tripalina Reserve Nowra, Yuin; Murrah Flora Reserve Bega Valley, Southern Yuin; Tweed Shire Council area, Madhima Gulgan Community Association; Cumberland Plain, Darug Country; Warre Warren Aboriginal Place, Darkinjung LALC.	McGrath (2017); NSW Rural Fire Service (2017); Darug Ngurra <i>et al.</i> (2019); Kerr (2019); McGrath (2019); Booth (2020) Brown (2016a) CSIRO <i>et al.</i> (2019); Environment Energy and Science Group (2020) Sleeman (2018)
Aboriginal lands	Fire planning completed for 23,390ha 457 ha burn area Many burn areas undefined	Rick Farley Reserve, Barkindji, Mutthi Mutthi and Ngyiampaa people; Hunter Valley, 9 Local Aboriginal Land Councils (LALCs) and Traditional Owner groups; Tathra & Bega Valley, Bega LALC; Minyumai IPA, Bandjalang Clan of the Bundjalung Nation; Ngunya Jargoona IPA, Nyangbul Clan of the Bundjalung Nation; The Willows-Boorabee IPA, Ngoorabul Country; Wattleridge and Tarriwa Kurrukun IPAs, Banbai Country; Dorrobbie Grass Reserve, Widjabul/Wiyabul of the broader Bundjalung peoples; Nimbin Rocks and land around Lismore, Ngulingah Aboriginal Land Council Working on Country team; Lismore, Jagun Alliance Aboriginal Corporation; Casino, Casino Boolangle Land Council; Kyogle, Gugin Gudduba Land Council; Jubullum, Wahlabul Country; Eurobodulla, Batemans Bay & Mogo LALCs; Griffith, Griffith LALC; Yass, Onerwal LALC;.	Booth (2020); Bush (2019); Brown (2020) Tamarind Planning (2017) Kerr (2019) Holmes <i>et al.</i> (2009); McKemey and Ngoorabul Community (2018); Kerr (2019); McKemey <i>et al.</i> (2019a) Maclean <i>et al.</i> (2018); McKemey and Patterson (2018); McKemey and Patterson (2019); McKemey <i>et al.</i> (2019b); McKemey and Banbai Nation (2020) McKemey and Wahlabul Nation (2018); Environment Energy and Science Group (2020) Environment Energy and Science Group (2020)
Private lands	150ha Mostly undefined	Bundanon Trust, Yuin Country; Mulgoa, Darug Country; Monaro Plains.	Maclean <i>et al.</i> (2018); Taylor (2018) McGrath (2017) Brown (2016b)
Undefined	Undefined	Muli Muli/Woodenbong area, Githabul rangers;	Kerr (2019)
NSW TOTAL	42,957 ha	STATE OF NSW LAND AREA = 80,115,000 ha	PROPORTION = 0.054%

State & Land Tenure Type	Approximate total known land area (ha)	Place and people	References
VIC			
Public lands	~317	Central western Vic (Bendigo), Dja Dja Wurrung Country; Cohuna - Barapa Iron Punt Track & Flannery NCR Rowlands, Barapa Barapa Country; Dyurrit (Mt Arapiles), Wotjobaluk Country.	Neale <i>et al.</i> (2019a) Wales (2019) Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.) Skurrie (2020)
Aboriginal lands	Undefined	Teesdale, Wadawurrung Country.	Corangamite CMA (2017); Maclean <i>et al.</i> (2018)
Trust/NGO lands	30	Nardoo Hills Reserves, Dja Wurrung Country.	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Private lands	Undefined	Skipton - Mt Emu Creek, Gunditjmara Country; Euroa	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.) Maclean <i>et al.</i> (2018)
Undefined	Undefined	Budgerum, Barapa Barapa Country.	Webster (2020)
VIC TOTAL	347 ha	STATE OF VIC LAND AREA = 22,744,400 ha	PROPORTION = 0.002%
ACT			
Public lands	8.7 ha + more undefined	Jerrabomberra Wetlands & other locations, Ngunnawal.	Weir <i>et al.</i> (2020) O'Mallon (2018); Guest Author (2019)
ACT TOTAL	8.7 ha	ACT LAND AREA = 235,800 ha	PROPORTION = 0.004%
SA			
Public land	Undefined	Adelaide, Kaurna Country.	Stewart (2020)
SA TOTAL	Undefined		

State & Land Tenure Type	Approximate total known land area (ha)	Place and people	References
TAS			
Public land	Undefined	Tasmanian Wilderness World Heritage Area, Palawa.	Lehman (2001)
Aboriginal land	Undefined	Truwana/ Cape Barren Island, Truwana rangers; lungtalanana/ Clark Island, Tasmanian Aboriginal Centre; Big Dog Island mutton bird rookery (Bass strait Islands); Preminghana IPA (North west Tasmania); Putalina IPA (Southern Tasmania); Piyura kitina IPA (Southern Tasmania); Trawtha Makuminya Aboriginal Land (Central Highlands); Chapel Island IPA (Bass Strait Islands); Kings Run Aboriginal Land (North West Tasmania).	Whiting (2017); Maclean <i>et al.</i> (2018) Costello and Standley (2020)
Private land	Undefined	Ross, Tasmanian Aboriginal Centre.	McIntyre (2018)
TAS TOTAL	Undefined		
QLD			
Public land	Undefined	Bunya Mountains, Bunya Mountains Murri Rangers of the Bunya People's Aboriginal Corporation.	Maclean <i>et al.</i> (2018); Kerr (2019)
Private land	Undefined	Sunshine Coast, Kabi Country; Warwick.	Cannan (2020) Maclean <i>et al.</i> (2018)
QLD TOTAL	Undefined		

2.3.3. Policies

In southeast Australia, community-driven cultural fire management appears to be driving the development of government policies. In the last eight years, eight policies have been developed in NSW, Victoria, Queensland and the Australian Capital Territory (Table 2.3). *The Victorian Traditional Owner Cultural Fire Strategy* was a landmark document that stated, ‘the purpose of the Victorian Traditional Owner Cultural Fire Strategy is to reinvigorate cultural fire through Traditional Owner led practices across all types of Country and land tenure; enabling Traditional Owners to heal Country and fulfil their rights and obligations to care for Country’ (The Victorian Traditional Owner Cultural Fire Knowledge Group 2019). In contrast, other states have developed brief operational plans related to Indigenous fire management (Queensland Parks and Wildlife Service 2012), the Tasmanian Parks and Wildlife Service expects to develop a policy in 2020, while South Australia has not produced a specific policy, although the DEW Fire Management Program Statement of Intent includes an acknowledgement and commitment to South Australia’s First People (Department for Environment and Water 2019). Nationally, the *National Bushfire Management Policy Statement for Forests and Rangelands* promoted Aboriginal use of fire (Forest Fire Management Group 2014). The Australasian Fire and Emergency Services Authorities Council’s *National Position on Prescribed Burning* included the key principle of acknowledgement of ‘Traditional Owner use of fire in the landscape’ (Australasian Fire and Emergency Services Authorities Council 2016).

The State and Territory policy development in Australia reflects the trend of other settler countries, where there has been a shift over the past four decades from hierarchical military models to more diverse, comprehensive and preventive management strategies for natural hazards (Dovers 1998; Cronstedt 2002; Thomassin *et al.* 2019). While there has been widespread recognition internationally of the important role Indigenous peoples could play in managing hazards on their ancestral lands and waters, Thomassin *et al.* (2019) concluded that this has yet to significantly transform the sector’s policies and practices, and collaborative decision making remains, in general, an aspiration more than a reality.

Table 2-3 Government policies related to contemporary cultural fire management in southeast Australia.

Government	Policy	Reference
New South Wales State Government	<i>NPWS Cultural Fire Management Policy</i>	Office of Environment and Heritage (2016)
	<i>FR [Fire & Rescue] NSW Cultural Burning Management Policy</i>	Fire & Rescue NSW (2017)
	<i>Draft Aboriginal Communities Engagement Strategy NSW</i>	NSW Rural Fire Service (2018)
Australian Capital Territory Government	<i>ACT Aboriginal Fire Management Plan</i>	ACT Government (2015)
	<i>Aboriginal Cultural Guidelines for Fuel and Fire Management Operations in the ACT</i>	Williamson (2015)
Victoria State Government	<i>The Victorian Traditional Owner Cultural Fire Strategy</i>	The Victorian Traditional Owner Cultural Fire Knowledge Group (2019)
	<i>CFA Koori Inclusion Action Plan (2014-2019), CFA Aboriginal Engagement Guidelines</i>	Country Fire Authority (2015); (Country Fire Authority 2018)
Queensland State Government	<i>Queensland Parks and Wildlife Service Operational Policy: Fire management partnerships with Traditional Owners on protected areas</i>	Queensland Parks and Wildlife Service (2012)
Tasmanian Government	The Tasmanian Parks and Wildlife Service is currently developing an Aboriginal Cultural Burning policy. The policy development is in the very early stages and is not expected to be completed until late 2020.	Dwyer (2020)
Council of Australian Governments	<i>National Bushfire Management Policy Statement for Forests and Rangelands</i>	Forest Fire Management Group (2014)

2.3.4. Benefits

The academic literature described 78 benefits grouped into 7 categories of contemporary cultural fire management in southeast Australia (Table 2.4). The frequency at which benefits were discussed (in decreasing order) were: cultural (coding frequency = 39), ecological/environmental (29), economic (13), wildfire management (13), political/self-determination (9), social (8), health and wellbeing (5) benefits (total = 116). Of these, 68% of the benefits described had actually been realised, while 39% were potential benefits that may result from cultural fire management. The categories of benefits that had mostly already been realised included cultural, social, health and wellbeing benefits. For ecological/environmental, economic, wildfire management and political benefits, approximately equal numbers of the identified benefits were realised and projected.

Maclean *et al.* (2018) found that Indigenous cultural fire management is a key management activity needed to manage Australia's biodiversity, including threatened species and ecological communities. They noted that the ecological benefits of on-Country cultural fire management were plentiful. The latest *Close the Gap Campaign Report* highlighted the benefits of cultural fire management in terms of land management, and the important role cultural burning activities play in passing on local knowledge and connection to land (The Lowitja Institute 2020).

Zander (2018) attempted to assess the economic benefits of Indigenous cultural fire management and found that the total costs per burn ranged between \$17,600 and \$46,000 and per ha between \$53 and \$54. However, not many respondents could identify the area burned, or managed in general, and due to a lack of cost data and the intangible nature of the main benefits, they refrained from conducting a benefit-cost analysis.

Table 2-4 Benefits of cultural fire management as described in the literature.

Benefit Type	Description	References
Cultural	Intergenerational transfer of cultural knowledge and practice.	Smith <i>et al.</i> (2018); Robertson (2019) McKemey <i>et al.</i> (2020a) Darug Ngurra <i>et al.</i> (2019) Weir and Freeman (2019)
	Increasing awareness of Lore.	Robertson (2019)
	Increasing knowledge and use of Indigenous languages.	Robertson (2019) McKemey and Patterson (2019)
	Ability to undertake cultural practice.	Robertson (2019)
	Protection of cultural diversity.	Hill (2003)
	Revitalisation of culture / enabling Indigenous people to connect with their culture.	Macleane <i>et al.</i> (2018) Eriksen and Hankins (2014); McKemey <i>et al.</i> (2019b)
	Linking people with natural resource production for food and other cultural practices.	Spurway (2018) Eriksen and Hankins (2014);
	Re-engaging as caretakers of Country.	Eriksen and Hankins (2014) Maclean <i>et al.</i> (2018) McKemey <i>et al.</i> (2020a) Darug Ngurra <i>et al.</i> (2019)
	Facilitating access to Country.	Macleane <i>et al.</i> (2018) McKemey <i>et al.</i> (2019b); Weir and Freeman (2019)
	Feeling support for meaningful work.	Macleane <i>et al.</i> (2018)
	Facilitating cultural knowledge exchange.	Macleane <i>et al.</i> (2018)
	Inclusion of cultural burning regimes into fire management plans.	Macleane <i>et al.</i> (2018)
	Protection of cultural heritage.	Macleane <i>et al.</i> (2018) Robertson (2019)
	Conservation of culturally significant species and ecosystems.	McKemey <i>et al.</i> (2019c)
	Fulfilling cultural responsibilities.	McKemey <i>et al.</i> (2019b)

	Rebuilding cultural knowledge.	McKemey <i>et al.</i> (2019c)
	Awakening identities.	Darug Ngurra <i>et al.</i> (2019)
	Giving back to Country.	Darug Ngurra <i>et al.</i> (2019)
	Intercultural learning.	Darug Ngurra <i>et al.</i> (2019); McKemey <i>et al.</i> (2019b)
	Increasing, refining and developing (cultural and ecological) knowledge.	Spurway (2018)
	Community doing business.	Weir and Freeman (2019)
	Getting away from racism and bigotry.	Weir and Freeman (2019)
	Feeling free and relaxed.	Weir and Freeman (2019)
	Connecting with each other.	Weir and Freeman (2019)
Social	Building of self-esteem, pride and a sense of belonging for local Aboriginal people.	Maclean <i>et al.</i> (2018)
	Building social capital when the wider Aboriginal and non-Aboriginal community see rangers successful caring for their Country.	Maclean <i>et al.</i> (2018)
	The building of knowledge networks and social capital via regional fire workshops.	Maclean <i>et al.</i> (2018)
	Increasing feelings of empowerment through Indigenous people leading fire management planning on their land.	Maclean <i>et al.</i> (2018)
	Developing and strengthening partnerships between Indigenous and non-Indigenous organisations.	Maclean <i>et al.</i> (2018)
	Receiving greater public awareness and increased recognition of the roles of Indigenous fire managers.	Maclean <i>et al.</i> (2018)
	Education and training opportunities for non-Indigenous managers to learn about Indigenous cultural fire management.	Maclean <i>et al.</i> (2018)
	Understanding the importance of women's fire knowledge.	Spurway (2018)

Economic	Indigenous fire management partnerships and activities have now spread across the country and offer an important opportunity for Indigenous livelihoods and on-Country economic enterprises. There is great potential for future enterprise development which would bring many other benefits.	Maclean <i>et al.</i> (2018)
	Fire activities create jobs for local Indigenous people that involve work valued by Traditional Owners and rangers.	Robinson <i>et al.</i> (2016)
	Potential savings in weed control, stronger growth in native pastures, carbon abatement and reduction in fire fuel loads.	Maclean <i>et al.</i> (2018)
	Economic benefits from the prevention of wildfire as a direct result of sharing cultural burning knowledge with the wider community and the protection of assets, including infrastructure and neighbouring farming properties, from wildfires.	Maclean <i>et al.</i> (2018)
	Providing employment and training pathways for young people, and meaningful employment for Indigenous people.	Maclean <i>et al.</i> (2018) Neale <i>et al.</i> (2019a) Lehman (2001)
	An increase in designated Indigenous positions in government agencies.	Maclean <i>et al.</i> (2018)
	More opportunities for Indigenous people to access senior government positions.	Neale <i>et al.</i> (2019a)
	Future boosts to the regional economy from improved biodiversity (parks as nice places to visit) resulting from cultural fire management.	Maclean <i>et al.</i> (2018)
	Further economic benefits included those that would come from increased employment opportunities for Indigenous land managers (and the flow-on effects for families and communities of increased family income, meaningful employment, connection with Country).	Maclean <i>et al.</i> (2018)
	In some instances, reduced wildfire fighting costs to government by having place-based remote fire crews.	Maclean <i>et al.</i> (2018)
	Indirect economic benefit relates to the cost savings when controlling weeds through Indigenous cultural fire management and the avoided damage that weed incursions do to native ecosystems.	Maclean <i>et al.</i> (2018)

Ecological/ environmental	Fire is critical to the health of Country.	Darug Ngurra <i>et al.</i> (2019) Spurway (2018)
	Cultural fires regenerate the bush and heals the land, leading to the restoration of healthy environments.	Kerr (2019) Eriksen and Hankins (2014) Maclean <i>et al.</i> (2018) Darug Ngurra <i>et al.</i> (2019) Spurway (2018)
	Cultural burning used to protect threatened species and their habitat, such as the koala and glossy black cockatoo.	Robertson (2019) Maclean <i>et al.</i> (2018)
	Cultural burning's potential use as a tool against the dieback of vegetation.	Robertson (2019)
	Protection of RAMSAR wetlands from the incidence of wildfire.	Maclean <i>et al.</i> (2018)
	The benefits of lower intensity cool vs hot burns, and mosaic, patch burns vs hectare wide burns.	Maclean <i>et al.</i> (2018) Weir and Freeman (2019)
	Native vegetation management, including native species regeneration from cool burns; managing native woody vegetation and seed banks.	Maclean <i>et al.</i> (2018) Darug Ngurra <i>et al.</i> (2019)
	Managing exotic weeds with fire (rather than chemicals).	Maclean <i>et al.</i> (2018) Darug Ngurra <i>et al.</i> (2019)
	Cultural burns use less chemicals than other burning methods.	Weir and Freeman (2019)
	Managing at a local place-based scale.	Maclean <i>et al.</i> (2018) Bardsley <i>et al.</i> (2019)
	Cultural burning benefits native fauna and maintains key habitat resources.	McKemey <i>et al.</i> (2019b) Spurway (2018) Weir and Freeman (2019)
	Cultural burning achieved a broad range of objectives encompassing conservation and knowledge and capacity development for Indigenous rangers and non-Indigenous scientists.	McKemey <i>et al.</i> (2019b)
	Maintaining or improving ecological or biodiversity values.	Lehman (2001) Bardsley <i>et al.</i> (2019) Robinson <i>et al.</i> (2016)
	Management at the landscape scale.	Robinson <i>et al.</i> (2016)
	Cool burns maintain important micro climates in the ecosystem by protecting the canopy and root systems of plants.	Weir and Freeman (2019)

Wildfire management	Cultural burning was adopted for its risk mitigation potential.	Weir <i>et al.</i> (2020)
	Cultural burning reduces fuel loads.	Robertson (2019) Weir and Freeman (2019) McKemey <i>et al.</i> (2019b)
	Cultural burning protects infrastructure.	Robertson (2019)
	Cultural burning reduces the risk of, and destruction caused by, wildfire.	Lehman (2001) Maclean <i>et al.</i> (2018) Spurway (2018) Weir and Freeman (2019) McKemey <i>et al.</i> (in press)
	'We never feared fire or were worried about being burned out because we had it totally under control' - Noel Butler (Budawang Elder).	Kerr (2019)
	Insights from Indigenous Australian fire management can help inform enhanced fire management practices. Reintroducing fire into some landscapes by drawing on Indigenous knowledge will not prevent wildfires but it may reduce their impact.	Lindenmayer (2003)
	The retention, revival, and integration of the Indigenous fire knowledge can be used to aid ongoing debates on how to coexist with wildfire today. A greater recognition of this traditional understanding of the environment could aid current struggles to manage the growing frequency of devastating wildfires if it is acknowledged by, and incorporated into, the practices of wildfire management agencies.	Eriksen and Hankins (2014)
Health and wellbeing	An Aboriginal fire fighter linked the well-being of the Country with her own personal well-being through working with fire in NSW. This sense of well-being is consistent with the findings of the Burgess <i>et al.</i> (2005) study of the health benefits associated with Indigenous burning practices, which included increased physical, mental, and social health.	Burgess <i>et al.</i> (2005); Eriksen and Hankins (2014)
	Health and wellbeing benefits related to cultural burning included the alleviation of mental health issues by local Indigenous land managers, an increase in exercise and improved nutrition, psycho-social benefit of getting back on Country and importantly spiritual health.	Maclean <i>et al.</i> (2018)
	Cultural fire management provides emotional and physical sustenance.	Darug Ngurra <i>et al.</i> (2019)
	Many people spoke about how fire management is an opportunity for healing Country, healing themselves, and healing fraught relationships, all at the same time. At many of the meetings diverse people came together to speak about this context, and to find better ways to live and work together.	Weir and Freeman (2019)

Political (self-determination)	Enabling Indigenous people into the fire policy-making role in a manner that respects their legal, cultural and human rights provides opportunities for addressing Indigenous economic and social development... contributes to Australian goal of reconciliation... leads to a greater understanding of the nature of relationships between people and Country.	Hill (2003)
	The role of fire as an educator is also important for the non-Indigenous participants. The revival of cultural burns signals two-way relationality: 'Yellomundee is now acting how it always has in regards to a place of cultural exchange.' Darug Country is also teaching Landcare groups and Rural Fire Service participants that fire is a non-threatening living entity. Country cares by enabling community participation, a place, and an activity, that provides and nurtures reciprocity.	Darug Ngurra <i>et al.</i> (2019)
	Universally, people spoke of the importance of the Recognition and Settlement Agreement in changing how the government agencies – DELWP and PV – related to Dja Dja Wurrung peoples and their corporate group, DDWCAC. According to most, the agreement provided the conditions-of-possibility for collaboration, particularly through its financial provisions and placing legal obligations on the agencies to consult with DDWCAC on land management issues. As one non-Indigenous manager noted, the agencies had 'engaged' prior to the agreement, but it was only afterwards that they 'really went from informing to inclusion'... The collaboration is materially and structurally redistributing greater control over Country into the hands of Aboriginal traditional owners. What is occurring is not decolonisation in the sense of a complete and irreversible transfer of authority, or withdrawal of settler colonial government, but rather the iterative decolonising renovation of the political and practical dominance of settler agencies. These are modest but real gains with nascent and unpredictable effects on those involved. Slowly, resources and authority are less solely on the side of the government and its agencies.	Neale <i>et al.</i> (2019a)
	Many decades after being displaced from their ancestral lands, the Banbai people have, for the first time, been empowered to reintroduce cultural burning at Wattleridge IPA.	(McKemey <i>et al.</i> 2019b)
	In 2000 the Parks and Wildlife Service is set to invite our Tasmanian Aboriginal community to participate in the reintroduction of Aboriginal fire regimes in the World Heritage Area. Given the degree of frustration and disappointment which has been felt by Aboriginal people in recent decades over the lagging pace of political change, the ability to manage and protect such a large area of Tasmania has the potential to be an even greater victory than winning legal titles to the small areas handed back in 1995.	Lehman (2001)
	The challenge is not just to bring differing epistemologies together to generate new knowledge, but also to overcome an historical unwillingness to undertake such actions. Truth and reconciliation is vital to facilitate societal healing, but it will also be the key trigger to facilitate openness about past failings to normalise the inclusion of Indigenous biocultural practices in Australian environmental management.	Bardsley <i>et al.</i> (2019)
	For Aboriginal and Torres Strait Islander peoples, engagement in disaster risk management potentially has broader implications. The current debates around Indigenous ecological knowledges provide support for arguments for stronger	Spurway (2018)

	native title and land rights mechanisms that empower Indigenous peoples and guarantee access to Country. The growth and sustainability of the Indigenous Estate, the importance of native title, land rights and access to Country are important considerations in caring for Country and, by definition, disaster risk reduction and Indigenous livelihoods. The lessons learned from Australia's First Peoples is that these issues cannot be separated out, they are part of an integrated whole: caring for Country equates with reducing natural disasters and sustaining political economies based on lands and waters under Indigenous custodianship. The issues raised in the literature connect to Australian First Peoples' broader struggles for equitable development and basic human rights.	
	Fire management is not simply a technical matter but is about values, and thus it is also political. This includes whose risk mitigation priorities matter, and whose fire management is authorised, funded, and taught. In Australia, this is overlayed with fraught histories of engagement between Indigenous and other people, which Indigenous people have to confront daily.	Weir and Freeman (2019)
	Australia's emerging fire management engagements are important opportunities for positive learning and collaboration, with potential to grow recognition of Indigenous peoples' priorities, as well as to help decolonise relationships between peoples and with nature... In the ACT the government is re-framing its fire management program in response to justice principles, a pathway that is facilitated by assumed synergies with ecological and risk goals; however, a much more comprehensive response is needed to support the authority and governance of the traditional custodians. More than partnerships and contracts, First Nations need to be supported to be First Nations through the sharing of resources and jurisdictional power. This requires the nation state to more comprehensively address the matter of nested sovereignties.	Weir <i>et al.</i> (2020)

2.3.5. Barriers

The literature described 22 types of barriers to contemporary cultural fire management in southeast Australia (Table 2.5). The frequency at which barriers were discussed (in decreasing order) were: lack of recognition (coding frequency = 14), protocols (14), legislation and regulation (8), application of cultural burning (8), power (7), knowledge (6), partnerships and agreements (4), lack of trust (4), ecological understanding (4), resourcing (4), capacity (2), wildfire risk (2), public perceptions (2), training requirements (2), access to land (1), cultural links and protocols (1), altered landscapes (1), fire suppression policies (1), climate change (1), sharing benefits (1), weather (1) and infrastructure (1) barriers (total = 89).

Table 2-5 Barriers to cultural fire management as described in the literature.

Barrier	Examples	References
Lack of recognition of Indigenous knowledge and land management practices	Lack of meaningful recognition of Indigenous knowledge by authorities, scientific community and/or organisations.	Kerr (2019) Cary <i>et al.</i> (2003) Eriksen and Hankins (2014) Darug Ngurra <i>et al.</i> (2019)
	Conflict between Western knowledge systems and Aboriginal cultural learning pathways.	Kerr (2019)
	Lack of support to implement fire using cultural practices rather than Western ways.	Kerr (2019)
	Limited appreciation of the benefits of Indigenous peoples' role in fire management.	Hill (2003)
	Different cultural understandings of fire.	Eriksen and Hankins (2014)
	Lack of recognition of the relationship between Indigenous people and fire by settler colonial society and its social, legal and economic structures and institutions.	Robinson <i>et al.</i> (2016)
	Unwillingness of agencies and others to engage in Aboriginal perspectives.	Smith <i>et al.</i> (2018)
	Reliance on narrow measurements of success (e.g. scientific biodiversity metrics) over other measures valued by Aboriginal peoples.	Smith <i>et al.</i> (2018)
	In the past, common practice was to privilege colonial voices and written texts over Indigenous people and their oral histories.	Smith <i>et al.</i> (2018)
	Misconceptions regarding the 'disappearance' of Indigenous fire practices.	Robinson <i>et al.</i> (2016)
	Treatment of Aboriginal and Torres Strait Islander peoples as unknowing, vulnerable victims in need of external, (usually) non-Indigenous expertise to make them aware of, and adapt to, the dangers of natural disasters... based on the misconception that Aboriginal peoples have lost contact with traditional ecological knowledges and their caring for Country strategies that ultimately could help reduce the likelihood of large scale wildfires.	Spurway (2018)
Partnerships and agreements	Conservation agreements are a key mechanism for formally recognising Indigenous fire knowledge and management. However, 'in principle' recognition does not always lead to successful incorporation of fire knowledge or the ongoing empowerment of Indigenous fire knowledge holders and fire managers.	Robinson <i>et al.</i> (2016)
	Lack of involvement of government agencies in Indigenous cultural fire management due to disengagement or lack of formal partnerships.	Tamarind Planning (2017)

	Lack of resources to facilitate agency engagement in cultural fire management.	Tamarind Planning (2017)
	There must be a cultural change within government agencies before they can increase engagement in cultural fire management.	Tamarind Planning (2017)
Access to land	Indigenous people were excluded from practicing cultural burning on traditional lands, fire management was undertaken by the authorities.	Kerr (2019)
Lack of cultural links and protocols	There is a need for a process to build the cultural protocols back into areas where cultural links have long been absent. Indigenous cultural governance and authority must be supported, as well as cultural learning pathways.	Kerr (2019)
Training requirements	Government agencies require people involved in fire management to be qualified fire fighters which excludes knowledgeable Elders and children. Government training requirements often distract from cultural burning pathways.	Kerr (2019)
	Relationships between government agencies and Indigenous staff are often perceived to be 'one way'. Indigenous people are required to gain a range of certifications from fire agencies before undertaking cultural burning, but their knowledge is not valued in turn.	Smith <i>et al.</i> (2018)
Knowledge	The 'Indigenous toolbox' containing traditional ecological knowledge and customary law is not well represented in fire management. Our challenge is to devise the 'bridging tools' between Indigenous and non-Indigenous toolboxes that would make the integration of information and knowledge from various sources work well.	Whelan (2003)
	While knowledge about Indigenous fire regimes is available for many parts of Australia, in other places the knowledge base has been (and continues to be) eroded.	Lindenmayer (2003)
	There are concerns that some of the Indigenous knowledge needed to burn Country 'the right way' is being lost due to 'not being on Country'.	Robinson <i>et al.</i> (2016)
	It is clear that the integration of actionable knowledge from Indigenous and other traditional sources into natural resource or hazard management remains difficult... The academic knowledge on regional Indigenous burning practices is insufficiently developed to warrant any strong claims to inform possible improvements in hazard and natural resources management.	Bardsley <i>et al.</i> (2019)
	There is much flux currently about fire management practices, including: the merits of prescribed burning in terms of protecting life and property; the science about the ecological impacts of hazard reduction burns; and, the role of Indigenous peoples' burning practices. Misunderstandings can derail important conversations because there are such different conceptual traditions and perspectives involved.	Weir and Freeman (2019)
	Traditional fire knowledge is a scarce resource... Some Aboriginal ranger groups had 'lost knowledge' around appropriate burning techniques, skills and experience while other Aboriginal people demonstrated the presence of this knowledge and skill.	Tamarind Planning (2017)

Lack of trust	The mixing of fire cultures often is hindered by a lack of cross-cultural trust.	Eriksen and Hankins (2014)
	Many Indigenous people have a historically-grounded mistrust of academic research and researchers.	Smith <i>et al.</i> (2018)
	Relationships between settler governments and Indigenous peoples are characterised by mistrust.	Thomassin <i>et al.</i> (2019) Neale <i>et al.</i> (2019a)
Power	The legacy of colonial constructs of power based on the oppression of Indigenous peoples and privilege of colonising peoples, leads to lack of access to the land and ability to practice cultural burning.	Eriksen and Hankins (2014)
	Langton (1998) highlights how misrepresentations, tropes and asymmetric power relationships have impeded effective application of Indigenous fire knowledge for decades.	Robinson <i>et al.</i> (2016) Langton (1998)
	Control needs to be meaningfully invested in Aboriginal peoples, 'when Aboriginal people are undertaking each step of the burn'.	Smith <i>et al.</i> (2018)
	General recognition of the importance of involving Indigenous peoples in natural hazard management strategies and structures has not led to a significant transformation of the sector, nor has it led to the devolution of decision-making power over natural hazards management from government to Indigenous peoples inside or outside the sector.	Thomassin <i>et al.</i> (2019)
	Aboriginal leadership is central, but what is also needed is for the government to embrace Aboriginal Australia and our traditional fire management practices... throughout Australia there is much more healing that needs to be done for such intercultural engagement to progress and be more meaningful for Indigenous people, including in material terms.	Weir and Freeman (2019)
	Formalizing cultural fire worked to disempower some Aboriginal participants, in alerting them to the scope and complexity of fire legislation and by formalizing their previously informal/unregulated burning.	Tamarind Planning (2017)
Altered landscapes	Australian landscapes are now substantially modified from those managed by Indigenous Australia- factors like weed invasion can dramatically alter fire regimes and fire impacts on landscapes and ecosystems.	Lindenmayer (2003)
Appropriate protocols for cultural sites and knowledge	Fire management sometimes lacks protocols for access and management of culturally significant sites during burning.	Eriksen and Hankins (2014)
	Lack of protocols for access to, storage of and sharing Indigenous knowledge.	Eriksen and Hankins (2014) Lindenmayer (2003)
	Lack of understanding of how knowledge is transmitted and used. Indigenous knowledge must be passed on by the 'right people to other right people'.	Eriksen and Hankins (2014) Lindenmayer (2003)

	History of exploitation of Indigenous knowledge by non-Indigenous people.	Lindenmayer (2003)
	Indigenous Australians continue to call for unique law and policy to protect Indigenous Australians' traditional knowledge and cultural expressions.	Robinson <i>et al.</i> (2016) Janke (2003)
	Knowledge of burning is not necessarily seen as something that can or should be shared freely without the responsibilities to Country that come with doing it.	Smith <i>et al.</i> (2018)
	It is not necessarily appropriate for detailed knowledge about cultural burning to be made freely available to the broader Australian public. This can be a source of tension between Aboriginal and non-Indigenous peoples and may lead to conflict surrounding ostensibly well-meaning projects. For example, efforts to establish national repositories of knowledge can be viewed by government agencies as a supportive step in facilitating cultural burning, but may actually be viewed by Aboriginal peoples as extensions of condescending governance approaches or extractive research agendas.	Smith <i>et al.</i> (2018)
	It should not be assumed that Indigenous peoples have traditional knowledge ready at hand or that they are willing or able to share it (particularly with the settler state). A fixation on traditional knowledge as the grounds for Indigenous recognition illustrate a key problem of participatory governance more generally, namely their failure to reconfigure power relations.	Lake (2013); Neale <i>et al.</i> (2019a)
	It should not be assumed that Indigenous peoples have or would be willing to share Indigenous ecological knowledge/traditional ecological knowledge.	Thomassin <i>et al.</i> (2019)
	Non-Indigenous emergency management institutions also need to recognise Indigenous custodianship of knowledge and that sharing said knowledge is not automatic. Indigenous peoples have the right to decide who will access what kinds of knowledge and when. Controlling the content and flow of knowledge is important as knowledge has important cultural, social and spiritual significance and cannot simply be shared with anyone.	Spurway (2018)
Fire suppression policies	Colonial interests in Australia disrupted Indigenous use of fire through the removal of people from their lands and policy prohibition. In place of traditional Indigenous fire knowledge, policies derived from state and federal agencies established around the concept of fire suppression or firefighting have become a societal norm.	Eriksen and Hankins (2014)
Ecological understanding	Ecologists have emphasised that burning practices need to be carefully tailored to the specific features of the ecosystem they are intended to protect. In particular, there is ongoing debate about how certain aspects of fire regimes—such as fire frequency, extent, intensity and seasonality—interact with critical ecosystems and biota.	Robinson <i>et al.</i> (2016)
	There is a lack of relevant data about cultural burning and its benefits to biodiversity, risk to human life and property, and other management goals. Data are being collected through agency processes, however, the burns do not have the formal properties of a generic	Neale <i>et al.</i> (2019a)

	scientific experiment and most estimate it will be 10–20 years before there is a strong basis to speak confidently about ecological outcomes.	
	There are few data to demonstrate the outcomes of cultural burning in southeast Australia, from both scientific and cultural standpoints.	McKemey <i>et al.</i> (2019b)
	Ecological fire is not a widely accepted practice, as some ecologists (and or the broader community) dispute the need for more landscape fire.	Tamarind Planning (2017)
Climate change	Contemporary fire management efforts are primarily driven by the virtual certainty that global warming will increase extreme fire weather and lengthen fire weather seasons, leading to heightened levels of risk. Climate change projections for heightened fire risk have stimulated interest in fuel-reduction burning to mitigate wildfire effects. However, Australian studies have demonstrated that prescribed burning—including approximations of Indigenous practices, such as patch mosaic burning—has very different outcomes in different landscapes. Further ecological and fire-modelling research is needed to better understand the effects of patch mosaic burning on fuel management, and to link management actions directly to asset protection and risks to biodiversity in specific ecosystems.	Robinson <i>et al.</i> (2016)
Application of cultural burning techniques	Indigenous Australians inhabited a very diverse range of landscapes, it seems highly unlikely that a single traditional Aboriginal fire regime would have applied continent-wide... Indigenous knowledge is not a toolbox or recipe book to be strictly followed- instead it is an ethos of understanding, respecting and living with the environment, rather than fighting it.	Lindenmayer (2003)
	There exists an attitude that the historic use of fire by Indigenous people does not apply to the environment today due to environmental and demographic changes. It is important to recognize, however, that culture and knowledge are dynamic. From an applied standpoint Indigenous fire knowledge is fluid (e.g., changing with past climatic events), and the ability to read the landscape to know how, when, why, and what to burn comes with proper training.	Eriksen and Hankins (2014)
	Popular approximations of Indigenous fire practices ignore the culturally embedded aspects of these practices that determine the right time for burning; the kinship relationships that determine who can light fires for Country; and the knowledge of cultural sites and cultural resources that influence the pathways of fires at a very fine scale.	Robinson <i>et al.</i> (2016)
	There is a need to spend time to build the knowledge and capacity needed to burn Country appropriately because 'burning with a little bit of knowledge can be a dangerous thing'- Uncle Allan Murray... Important to note, is the need to exercise caution before the scaling 'up and out' of cultural burning practices across the landscape before Aboriginal managers are ready to take the lead. The focus should be on Aboriginal managers building their knowledge, experience and skills in the immediate future.	Maclean <i>et al.</i> (2018)

	Indigenous ecological knowledge/traditional ecological knowledge should not be considered a panacea to wildfire management, nor should it be privileged as the grounds for Indigenous peoples' involvement with the natural hazard sector. Today's natural hazard risk context is heightened by contemporary influences such as rapid shifts in climate and land use.	Thomassin <i>et al.</i> (2019)
	Aboriginal peoples in southeast Australia have had less opportunity to remain on their ancestral territories, giving them fewer opportunities to maintain the traditional practices and forms of occupation by which settler law recognises Aboriginal land rights.	Neale <i>et al.</i> (2019a)
	There are concerns that some communities may 'lose [their] confidence to burn' because of the need to accommodate 'new rules for burning' guided by programs and investors.	Robinson <i>et al.</i> (2016)
	In the contemporary Tasmanian context, understanding of Aboriginal burning practices is still poor. Reintroduction of Aboriginal fire regimes may no longer be achievable or desirable, given changes that have occurred in recent times, such as the impact of exotic species and the fragmentation of remnant vegetation types. The level of skill exercised in the timing and control of Aboriginal cultural fires will be difficult to emulate without the redevelopment of an intimate human association with these areas.	Lehman (2001)
Legislation and regulation	Tight, complicated and potentially confusing rules, regulations and legislation.	Maclean <i>et al.</i> (2018) Neale <i>et al.</i> (2019a) Weir and Freeman (2019) Tamarind Planning (2017)
	State-based fire permits, tenure arrangements and diverse institutions for broad-scale fire mitigation, often impede Indigenous customary fire practices, historically operating at fine-scale in the landscape through extended family groups. Developing balanced, respectful and appropriate measures, protocols, laws and/or policies is crucial to creating solid fire management knowledge partnerships and knowledge-sharing methods... There is inconsistent translation of legal and policy instruments that support innovative Indigenous fire knowledge translation into programs and practices across the continent.	Robinson <i>et al.</i> (2016)
	One of the most frequently mentioned barriers to Indigenous fire management was challenges in coordinating the cultural burn with Government agencies.	Zander (2018)
	Overly bureaucratic risk management and regulations that do not account for cultural knowledge and practice.	Smith <i>et al.</i> (2018)
	The key challenge for researchers and policy makers is in developing new frameworks (legislation, regulation, governance, financial and career support) that enable Indigenous people into a policy-making role that fully respects their rights.	Hill (2003)

Resources	It is difficult to secure long-term resources for good fire management. Necessary resources include resources for training and employing fire officers, opportunities to share knowledge about good fire management practices with neighbouring groups, and scientific and technical expertise to manage fire for different purposes.	Robinson <i>et al.</i> (2016)
	An identified barrier to future collaborations between Aboriginal and non-Indigenous peoples for the support of cultural burning included the uneven distribution of funding between government and Aboriginal land managers.	Smith <i>et al.</i> (2018)
	Settler governments have repeatedly failed to take Indigenous expertise seriously, and disparities in funding and resources remain clearly evident. Indigenous peoples' governance institutions are typically unfunded, or underfunded, operating within socio-economically disadvantaged communities that bear extensive consultation responsibilities and legal liabilities.	Thomassin <i>et al.</i> (2019)
	While government had 'endorsed' the collaboration they had not provided budgetary support, including for employing Dja Dja Wurrung individuals in contract and seasonal wildfire positions. Managers said 'roughly' AUD\$800,000 had to be reallocated within DELWP's regional budget over 3 years to fund these positions. Extra funds were also needed to support necessary training and certifications.	Neale <i>et al.</i> (2019a)
Sharing benefits	A key challenge that remains in relation to fire management partnerships relates to equitable benefit sharing.	Robinson <i>et al.</i> (2016)
Weather	One of the most frequently mentioned barriers to Indigenous fire management was balancing weather windows / conditions.	Zander (2018)
Capacity	Two of the most frequently mentioned barriers to Indigenous fire management were lack of capacity and availability of fire managers and high turn-over rate; and lack of volunteers and participation from community.	Zander (2018)
	There was a need for improved equipment, more advanced training and more frequent experience on fire grounds.	Tamarind Planning (2017)
Wildfire risk	Fire management agencies in southern Australia operate within a context that has significant potential for intense and extreme fires. The period since settler invasion began has involved massive, complex, and ongoing social and ecological changes, one cumulative effect of which dramatic rises in wildfire frequency and intensity. Human migration into peri-urban interfaces is continuing to amplify wildfire's human impacts.	Neale <i>et al.</i> (2019a)
	It is important to recognise that classical Indigenous fire regimes cannot, and did not, prevent the extreme wildfires that occur in southern Australia during intense fire weather conditions. Climate change scenarios modelled by CSIRO and others predict that we will experience more extreme events, more often. Our contemporary policy direction must be based on learning to live with the effects of such fires in the environment, as we will not be able to prevent them.	Hill (2003)
Infrastructure	Compared with northern Australia, fire management agencies in southern Australia operate within a context that has a greater number of public and private assets at risk of wildfires.	Neale <i>et al.</i> (2019a)

Public perceptions	The results of trial burns have already demonstrated the wisdom of caution. Early burns have already gone out of control – continuing the pattern of destructive firing which has characterised the European experience of wilderness in Tasmania to date. This will alarm nature conservationists and generate resistance to moving away from the defensive fire regimes of recent years.	Lehman (2001)
	There is some optimism from environmentalist groups and scepticism from government employees about the benefits of Aboriginal cultural fire management, which could lead to a potential knowledge controversy.	Neale <i>et al.</i> (2019a)

2.4. Discussion

Cultural fire management is in the process of being revived in southeast Australia, as our review of the literature demonstrates. The revival has been driven by Indigenous leaders, as well as a broad shift in Australian society. This shift includes a resurgence of Indigenous rights, responsibilities and land ownership, development of policies, and a change in values to respect and take pride in Indigenous culture (Weir *et al.* 2020). The Black Summer bushfire crisis of 2019-20 also drove the public to question Australia's fire management, and to consider alternatives such as Indigenous cultural fire management. The media's coverage displayed brevity and bravado; while the academic literature was cautious and considered. The media may have created expectations that cultural fire management could be a panacea to Australia's fire problems, while the academic literature used evidence-based research to discuss the benefits and barriers to cultural fire management. Both the media and academic literature appeared to display bias. For example, there was a lack of negative or critical news stories about cultural burning, and equally, there was a lack of cultural perspective and research (i.e. how to enhance the cultural practice) in cultural burning academic writing. As expanded on below, many questions remain, which could shape priorities for future research and communication with the broader public, if Indigenous cultural fire management continues to expand across southeast Australia.

There were 116 instances in the academic literature where the various benefits of cultural fire management were described (Table 2.4). Cultural, social, health and wellbeing benefits had mostly already been realised. For ecological/environmental, economic, wildfire management and political benefits, approximately equal numbers of the identified benefits were realised and projected. This possibly indicates that research participants were able to more easily demonstrate cultural, social and health/wellbeing benefits while the anticipated benefits for other categories are yet to be proven. Different methods may have been used to measure these benefits and, indeed, they could be considered to be different types of challenges. For environmental benefits, it is challenging to quantify the complex changes that take place with burning, and a relatively long time scale is required to observe ecological changes (Driscoll *et al.* 2010; Lindenmayer *et al.* 2012). For cultural/social benefits, the challenge lies in isolating the cause and effect and furthermore, there is a lack of theoretical models to describe socio-cultural change and impacts across the Western-Indigenous cultural systems (Satz *et al.* 2013). Consequently, cultural monitoring, evaluation and reporting (MER) is generally under-researched (Wexler 2014).

Furthermore, while many of the benefits of cultural fire management in southeast Australia have been described qualitatively, few studies took a quantitative approach. Zander (2018) attempted to quantify the economic benefits of Indigenous cultural fire management but found that a lack of data prevented a benefit-cost analysis. McKemey *et al.* (2019b) used cross-cultural (Western and Indigenous) science to assess the impact of cultural burning versus hazard reduction burning on the cultural keystone species, the short-beaked echidna. Several studies claimed that cultural burning assisted to protect threatened species, manage weeds and reduce wildfire risk, however, these examples did not present empirical evidence to support these claims. A forthcoming paper by McKemey *et al.* (in press) compared the impact of Indigenous cultural burning with wildfire on the threatened Backwater grevillea (*Grevillea scortechinii* subsp. *sarmentosa*) in NSW. This research found that cultural burning had less impact than wildfire on the shrub's population and reproduction, whilst also decreasing fuel loads. Maclean *et al.* (2018) developed a national framework to report on the benefits of cultural fire management. This framework sets an agenda for future monitoring projects, to begin to fill the gaps in our shared knowledge across a transdisciplinary range of outcomes.

In regard to economic benefits, the academic literature mainly focused on Indigenous employment and enterprises. The benefits for wildfire management were mentioned but not quantified. Through a brief investigation, we found that the state and territory governments spent more than A\$5.5 billion to support fire and emergency services across Australia and New Zealand in 2018/19 and Australia had more than 290,000 personnel and thousands of specialist vehicles, according to the Australasian Fire and Emergency Service Authorities Council (Cox 2019). In 2019, the Federal Government announced an additional A\$3.9 billion for an Emergency Response Fund. Each year 'disaster-level' wildfires cost Australia an average of A\$77 million (Australian Institute of Criminology 2004). It has been suggested that for every dollar spent on prevention, \$22 can be avoided in suppression costs (The Senate Select Committee on Agricultural and Related Industries 2009). The Firesticks Alliance developed an initial \$100 million proposal to fund a nationally recognised, accredited cultural fire management training and mentoring program. This proposal was focused on empowering communities in the revival and sharing of cultural knowledge and practice across pilot regions throughout Australia. The aim was to support a cultural landscape approach to improve the health and resilience of Country and communities (Costello and Standley 2020). This could potentially improve cultural and natural values of Country while reducing the incidence, extent and impacts of wildfire over the long term in southeast Australia. These types of cultural fire programs could cost a fraction of current expenditure on prevention, mitigation,

response and recovery to wildfires. While this is speculative at the current time, cost benefit economic analysis of cultural burning could be undertaken in future for well-documented case studies, similar to other studies that have documented economic values of cultural practices and Indigenous knowledge (for example, see Gray *et al.* 2006 and Blackwell *et al.* 2019).

The literature also lacked detail on the area of land where contemporary cultural fire management was being practiced in southeast Australia (Table 2.2). We were able to develop rough approximations for the ACT, NSW and Victoria, which showed that less than 1% of the total land area of each of these states was being culturally burnt. Cultural burning was mostly documented on public and Aboriginal land. Considering that the majority of Indigenous people live in southern Australia, and they are southern Australia's largest land rights holders (Weir and Freeman 2019), cultural fire management is an underutilised practice. There were 89 instances in the academic literature where barriers to cultural fire management were described, and we grouped these into 22 categories (Table 2.5). Considering the breadth and significance of these barriers, it is not surprising that cultural fire management has only recently been revived in southeast Australia, and only over a small proportion of land. Many of the barriers seem insurmountable, and if cultural fire management is to be reinstated more widely, Indigenous fire practitioners have indicated it is likely to take many generations to see the results of landscape-scale cultural fire management.

The numerous Indigenous cultural fire management projects (Table 2.2) are supported by eight relatively recent policies created by state and territory governments of southeast Australia (Table 2.3). However, they are mostly short-term, small-scale, grass roots projects. In the cases where cultural fire management has been successfully reinstated as an ongoing practice, Indigenous leadership, extraordinary relationships, strong agreements and transformational change seem to be keys to success (Neale *et al.* 2019a). Neale (2020) stated that in the absence of robust budgets or a clear longer-term commitment by governments, future projects will continue to rely on persuasion, improvisation and intercultural diplomacy. Victorian (The Victorian Traditional Owner Cultural Fire Knowledge Group 2019) and NSW (Office of Environment and Heritage 2016) policies provide examples of ways in which governments are trying to move forward to support Indigenous cultural fire management, but these policies could fall short of providing the drivers and funding needed for cultural fire management to be applied across land tenures, across a broad landscape. In northern Australia, it took the introduction of an entirely new industry, a carbon economy based on savanna burning, to facilitate the reinstatement of Indigenous Traditional Owners as fire managers on their ancestral clan estates (Murphy *et al.* 2015). Neale *et al.* (2019a) found that, for the Dja Dja Warrung people, a Recognition and Settlement Agreement with the Victorian Government and its

corresponding financial provisions and legal obligations, along with the leadership and commitment of managers within government agencies, were key factors for the success of the *djandak wi* cultural burning program. With the advantage of being based on Indigenous land, the NCC Firesticks project (NSW) was considered a success due to its innovation: in enabling use of cultural fire, promoting its benefits, bringing Indigenous stakeholders and mainstream agencies together and in establishing pathways for future collaborations (Tamarind Planning 2017). At Rick Farley Reserve (NSW), success resulted from adopting a deeply cultural framework (Booth 2020; Ridges *et al.* 2020). In the ACT, the keys to a successful cultural fire management program included the critical role of motivated individuals and good relationships, with the First Nations being supported by government and community to lead the way (Weir and Freeman 2019). Smith *et al.* (2018) identified some keys to successful and supportive collaborations as ‘a shared emphasis on Aboriginal leadership, joint decision-making and a willingness amongst non-Indigenous partners to give up some of their control and authority’.

Steffensen (2020: 213), Indigenous fire practitioner and leader, outlined his vision for the future:

‘We need to work towards a whole other division of fire managers on the land, looking after Country in all the ways possible, which includes fire as well as other practices. A skilled team of Indigenous and non-Indigenous people that works with the entire community, agencies and emergency services to deliver an effective and educational strategy into the future. One that is culturally based and connects to all the benefits for community.

To do that we need to draw on all of our Aboriginal expertise to train people and start upskilling the fire managers of the future. To allow Indigenous practitioners from all states to bring together their values and leadership. We need to see three-year training courses of learning out on Country to graduate our Indigenous fire practitioners... we need to start training the trainers, building the teams, getting people out there on the many different levels. Build from the foundation of Aboriginal knowledge as the practical knowledge base to work from, and adding the Western knowledge to support a stronger solution.’

An expansion of cultural fire management could include: Indigenous engagement in fire management and wildfire recovery through employment, contract services and collaborative fire management initiatives (Neale *et al.* 2019b); Indigenous mentoring and training programs (Costello and Standley 2020); empowering local communities to take an active role in decision-making by building community skills and capacity and providing a greater sense of custodianship; increased Indigenous involvement in policy and planning; increased recognition of Indigenous knowledge

and cultural burning as a treatment strategy on various land tenures (Costello 2019); payments for ecosystem services; research to better understand Australia's fire history and the contemporary application of cultural fire management (as per Bardsley *et al.* 2019 and Smith *et al.* (2018); and use of cross-cultural knowledge (Indigenous and Western science) for fire management (McKemey *et al.* 2019b).

Several studies have demonstrated the wide array of benefits which accrue from investing in Indigenous natural resource management (NRM). For example, Social Ventures Australia (2016a) concluded that, between the 2009-15 financial years, an investment of \$35.2m from Government and a range of third parties in Indigenous NRM, generated social, economic, cultural and environmental outcomes with an adjusted value of \$96.5m, which is about \$3 return for every \$1 invested. While Indigenous Australians have a rights and interests in 40% of Australia's land (Department of Prime Minister and Cabinet 2018), manage 55% of the National Reserve System (Department of Environment and Energy 2019), and are custodians for at least 59.5% of threatened species habitat (Leiper *et al.* 2018), Preece (2019) claims that they receive only 6% of the Federal conservation estate budget. Many Indigenous communities wish to increase their opportunities to care for Country (Zander *et al.* 2013) and Zander and Garnett (2011) found that Australians could be willing to pay from \$878m to \$2b per year for Indigenous people to provide environmental services. This is up to 50 times the amount currently invested by government. In southeast Australia, where small-scale cultural burns have been demonstrated in many places over the past decade, growing this cultural and NRM practice to the landscape-scale could be considered a priority for investment.

The Bushfires Royal Commission (2020) provided an opportunity for Indigenous voices to be heard. Of the seven matters identified for inquiry through the Bushfires Royal Commission relating to the Black Summer bushfires of 2019 – 20, an entire matter was devoted to 'any ways in which the traditional land and fire management practices of Indigenous Australians could improve Australia's resilience to natural disasters' (Royal Commission into National Natural Disaster Arrangements 2020). This is in contrast to past bushfire inquiries, most of which have ignored the experiences, concerns, rights and interests of Indigenous peoples (Williamson *et al.* 2020). Some past bushfire inquiries have considered Indigenous fire management however, they concluded that there is very limited scientific information available to inform its effectiveness for wildfire management, or have focussed on past Indigenous burning practices while overlooking the opportunities that exist today (Esplin *et al.* 2003; Environment and Planning Committee 2017; Neale *et al.* 2020a). Williamson *et al.* (2020) suggested that the most urgent forum where

Indigenous people must have a strong presence is in the context of post-disaster inquiries and commissions, including any co-design of new policies and programs created in response to the disasters. To avoid duplication of findings of previous bushfire inquiries and widen the scope of our understanding of Indigenous fire management, Neale *et al.* (2020a) recommended that the Commonwealth Government creates a funding stream specifically to develop Indigenous-led, long-term research projects supportive of new and existing Indigenous fire management initiatives in southern Australia, examining the social, economic and ecological benefits of these initiatives.

Indigenous cultural fire managers are seeking support to produce research that translates and communicates the holistic benefits of cultural fire management. Through a virtual fire circle held in April 2020, 47 participants from a range of Aboriginal communities and organisations and their enabling partners and supporters outlined their research priorities (Firesticks Alliance 2020). These included: a need to produce peer-reviewed evidence that is written in the best way to communicate with and influence policy makers; a need for greater collaboration with researchers to produce materials that will influence policy change; enabling Indigenous practitioners to properly collaborate so that they are recognised as the experts and authorities of research outcomes; tighter protocols around ethical research practices that foster Indigenous-led research; empowerment of Indigenous research partners to determine the research questions, the nature of research relationships and who should be conducting that research; and, research funding be shared to pay the research partners who are the experts and knowledge holders. A message that was clearly communicated by participants at the Southeast Australia Aboriginal Fire Forum was that the Indigenous knowledge of cultural fire management does not need to be validated by scientific knowledge (Smith *et al.* 2018). The ‘theory of whiteness’ suggests that the need for science to validate Indigenous knowledge is a hegemonic process (Owen 2007). Instead, perhaps well-documented case studies that articulate the shared understanding space are needed. Science is one way to generate knowledge for shared understanding, but Aboriginal culture has its own knowledge processes to enable shared understanding (for example, see Ridges *et al.* 2020). Any research into Indigenous cultural fire management must take a ‘Nothing about us, without us’ approach (Ball 2005; The Lowitja Institute 2020). While there is an upward trend in Indigenous voices being represented in the literature, it is imperative that Indigenous leadership, co-development and co-benefits are incorporated into ethical and respectful partnerships in the cross-cultural interface. Beyond this, the frame of reference in which research is conducted must also be reconsidered (for example, see Wright *et al.* 2012). These are transdisciplinary, cross-cultural outcomes that require diverse and innovative research approaches, and could be applied in similar contexts across the

globe. For example, Indigenous cultural fire management is increasingly being recognised and applied in post-colonial nation-states such as the Americas (Bilbao *et al.* 2010; Christianson 2014; Mistry *et al.* 2016; Lake *et al.* 2017; Eloy *et al.* 2019a) and Africa (Moura *et al.* 2019), although many of these Indigenous communities face similar challenges to those described for southeast Australia (Moura *et al.* 2019; Schmidt and Eloy 2020).

Morgan *et al.* (2020), in their review of the history and future directions of prescribed burning, predicted that Aboriginal involvement in fire management will increase in all jurisdictions of southeast Australia. If Indigenous cultural fire management is to continue to grow in southeast Australia, more funding, devolution of power and Indigenous control is required. Funding for projects, whether from governments, philanthropic organisations or payments for ecosystems and cultural services (as described in Ens 2012b), is required to build on the foundations established through existing cultural fire management projects. An Indigenous Elder at the 2018 National Indigenous Fire Workshop stated that we need ‘to take action to heal Country and share knowledge for the survival of all, lest we create our own ecological hell through inaction and bureaucratic paralysis’ (Reye *et al.* 2019). Participants of the 2019 National Indigenous Fire Workshop on Yorta Yorta Country called for a ‘monumental shift in mindset’ to include Indigenous knowledge and burning practices, with potential for ‘a stunning reconciliation outcome’.

2.5. Conclusion

Our review of the literature indicated that contemporary Indigenous cultural fire management is practiced over a very small proportion of southeast Australia, there are many potential benefits associated with cultural fire management but, at this stage in time, there are significant and widespread barriers to the expansion of cultural fire management practices. Collaborative research could assist through addressing some of the knowledge gaps, such as examining benefits, overcoming barriers, implementing policies and changing paradigms for research, management and cross-cultural relations. It is evident that there is general public interest, widespread media support, policies in place and outcomes from the Black Summer bushfire inquiries which could generate the momentum to propel the many grass roots cultural initiatives into longer term, well-resourced, landscape-scale Indigenous cultural fire programs in Australia’s southeast. As a community of research, academics may need to provide appropriate support, when invited, for practitioners and policy developers as Indigenous cultural fire management evolves in the post-colonial social-ecological systems of southeast Australia.

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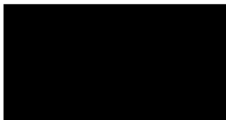
STATEMENT OF AUTHORS' CONTRIBUTION

We, the PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated in the *Statement of Originality*.

	Author's Name (please print clearly)	% of contribution
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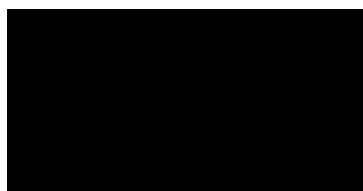
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Type of work	Page number/s
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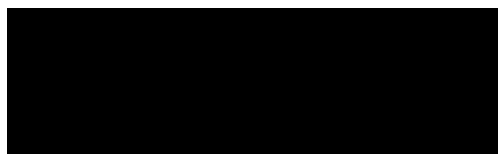
Name/title of Principal Supervisor: Prof. Nick Reid



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Principal Supervisor

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Chapter 3. Indigenous Knowledge and Seasonal Calendar Inform Adaptive Savanna Burning in Northern Australia

Title of Article:

‘Indigenous Knowledge and Seasonal Calendar Inform Adaptive Savanna Burning in Northern Australia’

Authors:

Michelle McKemey, Emilie Ens, Yugul Mangi Rangers, Oliver Costello and Nick Reid

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3.0. Abstract

Indigenous fire management is experiencing a resurgence worldwide. Northern Australia is the world leader in Indigenous savanna burning, delivering social, cultural, environmental and economic benefits. In 2016, a greenhouse gas abatement fire program commenced in the savannas of southeast Arnhem Land in the Northern Territory, managed by the Indigenous Yugul Mangi rangers. We undertook participatory action research and semi-structured interviews with rangers and Elders during 2016 and 2019 to investigate Indigenous knowledge and obtain local feedback about fire management. Results indicated that Indigenous rangers effectively use cross-cultural science (including local and Traditional Ecological Knowledge alongside Western science) to manage fire. Fire management is a key driver in the production of bush tucker (wild food) resources and impacts other cultural and ecological values. A need for increased education and awareness about Indigenous burning was consistently emphasised. To address this, the project participants developed the *Yugul Mangi Faiya En Sisen Kelenda* (Yugul Mangi Fire and Seasons Calendar) that drew on Indigenous knowledge of seasonal biocultural indicators to guide the rangers' fire management planning. The calendar has potential for application in fire management planning, intergenerational transfer of Indigenous knowledge and locally driven adaptive fire management.

Keywords: ecological calendar; Traditional Ecological Knowledge; cross-cultural; fire management; Indigenous fire; fire ecology; wildfire; wildland fire; Indigenous

3.1. Introduction

Wildfire management is an escalating issue globally, with economic, environmental, social and cultural consequences (Bowman *et al.* 2011; He *et al.* 2019; Williams *et al.* 2019; Moreira *et al.* 2020). In fire-prone regions such as the Americas, Australia and parts of Asia and Africa, wildfire management presents a formidable ongoing challenge that must be urgently addressed. Wildfire is also a growing problem in regions where it has not previously been a priority, such as southern Europe (Alcasena *et al.* 2019).

Indigenous peoples have been effectively managing fire on their ancestral estates for millennia. Beginning tens of thousands of years ago, hunter–gatherers around the world used fire to reduce fuels and manage wildlife and plants (Bowman *et al.* 2009). Australian Aborigines, who have inhabited Australia for sixty-five thousand years (Clarkson *et al.* 2017), maintained a complex system of land management using fire and the life cycles of native plants to ensure plentiful wildlife and plant foods throughout the year (Gammage 2011). Fire management is driven by an Indigenous group’s cosmovision, encapsulated in Australia’s First Nations peoples’ term ‘caring for Country’, whereby the maintenance and restoration of land and ecosystems is inextricably linked to human wellbeing, spirituality, kinship systems and culture.

In many nation-states following the onset of colonisation, traditional Indigenous fire management practices were disrupted through policies such as the removal of Indigenous peoples from their lands, prohibition of traditional practices and fire exclusion (Kimmerer and Lake 2001; Elder 2003). In recent decades, recognition of Indigenous knowledge and practice of fire management has led to the re-emergence of several Indigenous fire management programs (Russell-Smith *et al.* 2007a; Miller and Davidson-Hunt 2010; Armatas *et al.* 2016; Mistry *et al.* 2016; Lake *et al.* 2017; Eloy *et al.* 2019a; Moura *et al.* 2019). For example, in South America, following a period of wildfire suppression and prohibition of Indigenous fire practices, Indigenous groups and government agencies are working towards a participatory and intercultural fire management approach (Bilbao *et al.* 2019). While there is growing recognition of the important role Indigenous peoples could play in managing natural hazards on their ancestral lands, internationally, collaborative decision making is often considered to be ‘an aspiration more than a reality’ (Spurway 2018; Thomassin *et al.* 2019).

Northern Australia was colonised by Europeans from 1860 onwards, leading to the depopulation of ancestral Indigenous clan estates (‘Country’) and subsequent disruption to traditional fire regimes

in many areas (Russell-Smith *et al.* 2018). Prior to colonisation, fire was managed by Indigenous custodians through culturally driven, systematic, patchy, landscape-scale burning of Country. Following colonisation and disruption of traditional Indigenous fire practices, fire regimes became dominated by extensive wildfires occurring predominantly during the severe fire weather conditions of the late dry season, covering many thousands of square kilometres and causing significant environmental damage (Cooke 2009; Ansell and Evans 2019; Evans and Russell-Smith 2020).

From the 1990s, the establishment of community ranger groups and Indigenous Protected Areas (IPAs) facilitated many of Australia's Indigenous peoples to re-connect to, and participate in, land management activities (Altman and Kerins 2012). IPAs are areas of land and sea managed by Indigenous groups as protected areas for biodiversity conservation through voluntary agreements with the Australian Government. In 2020, IPAs contributed over one hundred million hectares, or 54%, of the National Reserve System of Australia (Department of Environment and Energy 2019).

From 1997, Indigenous people, fire researchers, fire management authorities and public and private funding agencies began to promote active restoration of customary Indigenous fire management in northern Australia (Cooke 2009). From 2006, Indigenous land management organisations commenced formal agreements with industry and government partners to off-set greenhouse gas (GHG) emissions through 'savanna burning'.

Savanna burning is described by the Australian Government (Australian Government 2019) as the 'savanna fire management—emissions avoidance method [that] credits activities that reduce the emission of greenhouse gases from fire in savannas in northern Australia, through a reduction in the frequency and extent of late dry season fires'. Tropical savanna ecosystems account for around 22% of the global land surface (Ramankutty and Foley 1999) and 50% of the total annual biomass is burned globally (Hao and Liu 1994). The seasonally dry tropics of northern Australia account for 12% of the world's tropical savanna biome and have global significance. In these ecosystems, fire is 'arguably the greatest natural and anthropogenic environmental disturbance' (Beringer *et al.* 2015) and the most important tool available to Indigenous peoples to manage Country (Yibarbuk *et al.* 2001; Ansell and Evans 2019).

By 2019, there were over 70 savanna burning projects across northern Australia (Ansell and Evans 2019), while Indigenous savanna burning projects in Arnhem Land (Figure 3.1) alone earned approximately \$10M AUD per annum (Morrison *et al.* 2018). These projects provide Indigenous rangers in remote, socio-economically disadvantaged communities with an opportunity to care for

their Country and earn income to support community development. For example, the Warddeken IPA Indigenous rangers' savanna burning program, using traditional and contemporary practices, has generated substantial revenue as a result of carbon offset sales. This program has also led to socio-economic and cultural outcomes, such as increased employment, skills, confidence, health, wellbeing, pride, maintenance of culture and Indigenous languages, and greater respect for Traditional Ecological Knowledge (TEK) (Social Ventures Australia 2016b). Ansell and Evans (2019) found that Traditional Owners participating in the broader Arnhem Land Fire Abatement (ALFA) project want to continue healthy fire management on their Country, see fewer wildfires, protect biodiversity and culturally important sites, maintain and transfer knowledge, as well as create a carbon abatement. They found that, whilst annually variable, the savanna burning projects are meeting these goals. Due to these successes, Australia's Indigenous savanna burning program is considered a world leader, with interest from peoples in savanna regions globally to instigate similar programs (Lipsett-Moore *et al.* 2018).

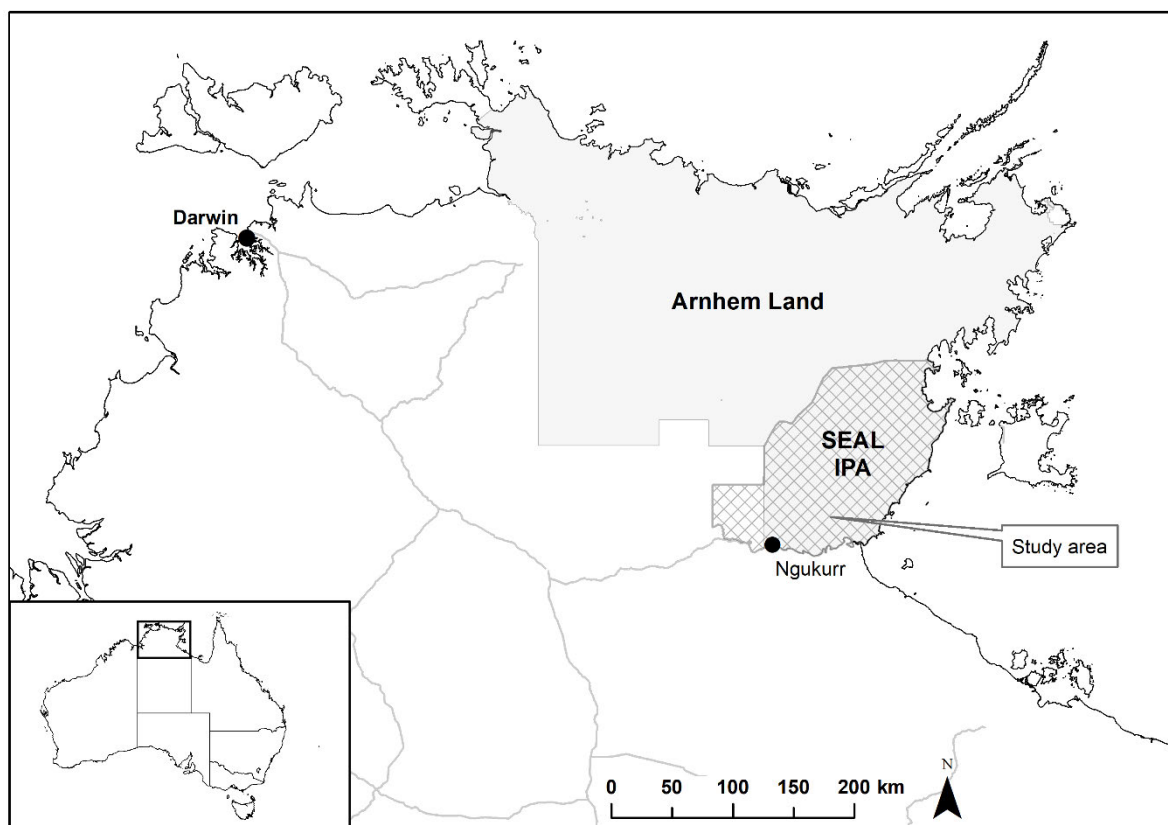


Figure 3-1 South East Arnhem Land Indigenous Protected Area (SEAL IPA), Northern Territory, Australia.

Indigenous savanna burning projects aim to use cross-cultural science (Indigenous and Western knowledge systems; Ens *et al.* 2015) for best-practice adaptive management of fire, incorporating natural and cultural values. Indigenous knowledge and languages are under grave threat globally (United Nations 2019b) and intergenerational transmission of this knowledge is constrained by

pervasive variables in the contemporary environment (Ens *et al.* 2016; Opare 2016). Around the world, seasonal calendars are viewed by Indigenous communities as an important way to collect and share Indigenous knowledge (Green *et al.* 2010) and to signify the profound connection between people, Country and the yearly cycle of change on Country (James *et al.* 2018). These calendars provide a graphical representation of Indigenous seasonal knowledge, including knowledge of the weather, ecological indicators, seasonal cycles of plants and animals, and their links with Indigenous culture and land uses (Prober *et al.* 2011).

Indigenous seasonal calendars have been used in the monitoring and adaptive management of natural resources, 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; Hatfield *et al.* 2018; Yang *et al.* 2019), water (Woodward *et al.* 2012) and fire regimes (Armatas *et al.* 2016), and to guide eco-health decision making (SantoDomingo *et al.* 2016). In Australia, many Indigenous seasonal calendars have been developed, based on phenological observations of local environments, and are often linked to practices such as harvesting of traditional resources and fire management (Carpentaria Land Council Aboriginal Corporation 2014; Hatfield-Dodds 2016). For example, some seasonal calendars depict ecological indicators or specific seasonal conditions as a guide for fire management (Carpentaria Land Council Aboriginal Corporation 2014; Kerr 2019), although this information is often not detailed for the primary purpose of the seasonal calendar. While seasonal calendars are generally popular for cross-cultural interpretation of Indigenous ecological knowledge, Prober *et al.* (2011) and Franco (2015) noted that seasonal knowledge is underutilised in natural resource management.

Our review of the scientific literature reveals that fire management informed by Indigenous knowledge is sophisticated, effective and widely underutilised across the globe. However, processes for sharing and understanding Indigenous knowledge are limited, and could contribute to improved management of social–ecological systems. In this study, we attempted to address this knowledge gap by sharing Indigenous knowledge of fire, and developing a fire and seasons calendar to improve adaptive fire management and communication. The objectives of our study were: to describe Indigenous fire knowledge and practice in South East Arnhem Land (SEAL) IPA (Figure 3.1); to explore how fire management affects cultural and ecological values; to use local Indigenous knowledge to develop a fire and seasons calendar for the SEAL IPA to guide savanna burning; and, to outline how the fire and seasons calendar can be applied to improve adaptive fire management and communication in northern Australia and other fire-prone regions and countries around the world.

3.2. Materials and Methods

3.2.1. Study Area

Northern Australia is one of the world's rare, internationally significant, large natural areas, comparable to wilderness zones such as the Amazon rainforests, the boreal conifer forests of Alaska, and the polar wilderness of Antarctica (Woinarski *et al.* 2007). Arnhem Land was declared an Aboriginal Reserve in 1931, and covers an area of 97 000 km². Due to its remoteness, Arnhem Land has retained many of its natural and cultural values, and is considered a refuge for Indigenous culture and native ecosystems, which have faced threats and significant degradation elsewhere.

The SEAL IPA was declared in 2016 covering an area of 19 170 km² on the western edge of the Gulf of Carpentaria in the Northern Territory and conserving extraordinary natural and cultural values (Gambold 2015). The Indigenous Yugul Mangi (meaning 'all of us,' i.e., Indigenous people of South East Arnhem Land) rangers were formally established in 2001 and manage the southern region of SEAL IPA in partnership with the Numbulwar Numbirindi rangers.

The Yugul Mangi rangers commenced the South East Arnhem Land Fire Abatement 2 (SEALFA2) savanna burning project in 2016, with the intention that 'this initiative will provide enough income for our rangers to continue proper management of fire throughout our IPA' (Gambold 2015). 'The SEALFA2 project applies strategic early dry season burning activities to reduce the total area that is burnt each year and to shift the seasonality of burning from [the] late dry season to early dry season [of the monsoonal tropical climate]. This reduces emissions because the fires are less intense and burn less Country each year' (Northern Land Council 2017).

3.2.2. Qualitative eco-cultural research

Qualitative ecological and cultural (eco-cultural) research was undertaken in the SEAL IPA during June 2016 and June 2019 (University of New England Human Ethics approval HE14-182 & 19-068, Northern Land Council Research Permit 86574). The Yugul Mangi rangers and SEAL IPA Elders were selected as collaborators due to their knowledge and practice of fire management. All participants resided in the town of Ngukurr (Northern Territory, Australia, Figure 3.1) at the time of the interviews and represented nine traditional Indigenous language groups from the SEAL IPA region. Ngukurr is a remote Aboriginal community with a population of 1149 people (Australian Bureau of Statistics 2019), although the population fluctuates as people move around among 'outstations' (isolated houses located on traditional clan estates) and other towns.

Twenty-one Indigenous participants (eight female, 13 male) were interviewed, ten of whom (four female, six male) were interviewed in both 2016 and 2019 (Table 3.1). The number of participants was limited by the low total number of Elders and rangers and the availability of participants during field work. Participants were coded according to gender (male [M] or female [F]) and role (Elder [E] or ranger [R]). Younger community members also participated in order to learn from the Elders and develop skills in undertaking research.

Table 3-1 Participants in 2016 and 2019.

Gender and role ^A	Interviewed in 2016	Interviewed in 2019	Interviewed in both 2016 & 2019	Total participants (<i>n</i>)
FE	4	5	3	6
ME	5	6	4	7
FR	1	2	1	2
MR	5	3	2	6
TOTAL	15	16	10	21

^A F = female, M = male, E = Elder, R = ranger.

Following an inductive approach, research methods included participatory action research, semi-structured interviews and focus groups in a meeting forum (Babbie 2013), conducted during field work in Ngukurr and SEAL IPA. For the participatory action research, a non-Indigenous scientist (MM) and the Yugul Mangi rangers participated in ground-based savanna burning in the SEAL IPA in order to collect information and photographs for the fire and seasons calendar.

Semi-structured interviews were conducted singly or in groups of up to four Elders or rangers. Interview questions were based on the themes of traditional and contemporary Indigenous fire knowledge and management; cultural values of fire, plants and animals; resource use; weather conditions, seasonal changes, biocultural indicators, and use of the fire and seasons calendar (Appendix 3.1). To facilitate discussion, information from five pre-existing seasonal calendars developed in 2000 by speakers of Roper River Kriol ('Kriol', the local Aboriginal language), Ritharrngu/Wägilak, Ngandi, Marra and Wubuy (Nunggubuyu) languages were used (Kriol Language Speakers and O'Donnell 2000; Mara Language Speakers and O'Donnell 2000; Ngandi Language Speakers 2000; Nunggubuyu Language Speakers 2000; Wilfred *et al.* 2000). Interviews were recorded audio-visually and transcribed. Interviews conducted in Aboriginal languages were

translated into English with the assistance of local community members. Interview results were coded *a posteriori* manually and grouped into themes (Saldaña 2015).

Focus group meetings were held at the Yugul Mangi rangers' headquarters and concentrated on working through blank calendar templates to fill in fire management activities and observations of seasonal changes throughout the year. A draft of the fire and seasons calendar was developed, and follow-up consultation was undertaken to provide feedback on the calendar. Senior language speakers at the Ngukurr Language Centre contributed to the calendar. The Indigenous rangers and non-Indigenous scientists worked together to finalise the calendar and develop the manuscript for publication.

3.3. Results

3.3.1. Traditional Indigenous Fire Management

Traditionally, burning was an important activity that was done purposefully by 'the old people' (Indigenous ancestors). Reasons for burning included: to renew plants and grass, open up Country, facilitate hunting, encourage bush tucker, communicate (signal between groups), improve safety, for cooking, to set up camp and for ceremony. Skills and knowledge about fire management were passed on from the old people orally and learned experientially. Some of the tools for traditional fire management included fire-drills, rocks, flint stone, firestick, dilly bag, paperbark (*Melaleuca* spp. bark) and pandanus (*Pandanus spiralis*) leaf. More recent tools include steel or knife, tin and matches. Burning was usually undertaken on foot, often when groups of people were out hunting. 'Mainly traditional burning was straight after the rain. When the rain stops the best time that we learnt to light fire is to go out with the old people hunting and they told us, burn here and burn there, it is only small patch burn'—MR.

3.3.2. Contemporary Indigenous fire management

Contemporary Indigenous savanna burning uses cross-cultural science for best-practice management, combining traditional and Indigenous knowledge with Western science. 'We are showing, not even Australia, but worldwide that we are managing our Country with the knowledge that has been passed down from generation to generation by our grandfathers and ancestors, and still is. Because we got modern [tools], like using helicopter to burn, all season matches, drip torch. We are still using our same knowledge—when to burn, how to burn ... We are doing the burning because our grandfathers did it before. Now they are gone, they taught us and we take note. Now

we are teaching our children, our future rangers, we are teaching them to take over our ranger program, including fire. Fire management in our ranger program is very important because fire brings back life’—MR.

Similar to traditional uses, fire is currently used for hunting, campfires, cooking, clearing around camp, to renew plants, ceremony, intergenerational knowledge transfer and to follow in the footsteps of the ancestors. More modern uses for fire also include: to earn income from carbon farming, to offset the burning of fossil fuels, to stop intense wildfires, to protect infrastructure, fire-sensitive areas and neighbours, and ‘to show Australia and the world we know how to burn using traditional knowledge and modern technology’—MR.

Contemporary burning uses both traditional and modern methods (Figure 3.2). Drawing on tradition, practitioners sometimes light fires the cultural way with sticks or paperbark, undertake burning walks where they follow traditional routes of the ancestors and light up the Country, and follow cultural protocols (e.g. kinship system) for land management. Burning is undertaken by community members, Elders and rangers. The right people must light the fire on clan estates and rangers must have permission from the right people before they can burn the land. ‘When we set up our ranger program it was set up with traditional kinship relations to the Country. To have the right people to light up the fire’—MR. Intense (‘hot’) fires and not following cultural protocols can cause conflict in the community. One of the rangers explained their relationship with the Traditional Owners: ‘[We (rangers) tell the Traditional Owners] this is your land, you have every right to tell us what to do, where to burn and where not to burn. That is showing them that they have got authority for the land, not us, the ranger group, it is them. It makes us feel happy that we are taking them out, and to learn more of our culture and the way our ancestors and our forefathers have burned’—MR.



Image 3-1. Yugul Mangi rangers lighting fires with (a) fire stick and (b) matches.

Current methods employ ground and aerial burning. Tools for burning include: lighters and matches, drip torches, four-wheel-drive vehicles, helicopters and an aerial incendiary (Raindance) machine. Technology such as CyberTracker, iTracker, GPS, satellites and camera trapping is used for monitoring. Training, support and information are provided by other ranger groups and through organisations such as Arnhem Land Fire Abatement (ALFA), NT Bushfires Council, Northern Land Council, Charles Darwin and Macquarie Universities, and the North Australia Fire and Rangelands Information (NAFI) website. Remote-sensed data have proved useful to improve fire management practices (Sharma *et al.* 2018) and remotely-sensed fire-scar maps are used to plan and review fire management. Contemporary burning generally begins in April and May (early dry season) and continues through to the end of July. ‘*We are doing cool burning now [June], right time burning*’—FR. ‘*The more time you burn when it is cooler, the more carbon credits you get*’—MR. Some patch burning is undertaken in August and September to ‘clean up’ areas that weren’t burned during the cool period. Factors influencing burning include: type of landscape/ecosystem (e.g. hills or savanna), weather (especially amount and timing of rainfall), fire history (when an area was last burnt), fire-sensitive areas (such as bush tucker areas, rainforest, rock art, sacred sites and sandstone escarpment) and infrastructure (outstations, camping and recreational areas, property boundaries). Good fire is considered to be low-intensity (‘cool’) fire which burns slowly, only burns the grass not the trees, allows animals to escape and is generally conducted during the colder months of April to July. ‘*The right time to burn is when it is cool and the fire burns slowly ... when we have heavy dew in the morning and the afternoon ... The wind picks up usually midday and then we burn and that helps us push the fire along*’—MR. ‘*The time to stop burning is when it gets very hot*’—ME. ‘Nugudwan faiya’ (Kriol for bad fire) are hot fires that burn the canopy, leave fire scars and black ash on the trunks of trees, burn in an arrowhead and are often ignited by lightning. ‘*A hot burn, that is a 'nugudwan faiya', that makes us unhappy. That is not right. Not only will the trees get burnt, it will stop the birds [wanting] to make their nest in there ... and even kill small lizards—the skink that climbs up the tree—kills the landscape*’—MR.

3.3.3. Savanna Burning

The Yugul Mangi rangers formally commenced savanna burning in 2016. During the first three years of operation, participants shared that savanna burning has:

- provided income for the rangers to buy work-related resources, including gators, trailer, vehicles, fuel, helicopter time, firefighting uniforms, drip torches, matches, Raindance machine and pay for casual employees

- supported rangers in their fire management by improving engagement with Western technology such as GPS, helicopters and satellite mapping whilst still using Indigenous ways of burning
- reduced wildfires by increasing early dry season burning.

A ranger explained how they combine traditional burning with modern technology: *‘It works by us doing traditional burning with our new Western technology ... Through the Indigenous way we know which part of the area that we come to burn and the right time of burning’*—MR. Other rangers explained the economic, cultural and environmental benefits: *‘Savanna burning benefits the Country and the ecosystems. Country is healthy. Brings in dollars for us to use in our rangers for more resource’*—MR. *‘The carbon money helps us to get more casuals, and fuel to take Elders on the chopper [helicopter] to look and to visit their Country’*—FR. However, many of the Elders interviewed had little understanding of savanna burning for GHG abatement, its application in the SEAL IPA or the income derived from this activity, as illustrated by the quote: *‘What is carbon?’*—FE. There was also a mixture of positive and negative sentiments expressed by various participants regarding the outcomes of savanna burning. Negative comments focused on: too much or ‘wrong way’ burning; detrimental impacts on bush tucker; lack of opportunity for community members to burn; mis-managed fire leading to wildfire; lack of education for young people, and that community members did not respect the work of the rangers. Positive comments focused on: continuing improvement in ranger management of fire; Indigenous Traditional Owners’ support of rangers; increased income and resources generated from savanna burning; effective use of cross-cultural science; involvement of community members, Elders and young people in burning programs and their emotional wellbeing related to Indigenous fire practices; the potential for ‘right way’ burning to restore important bush-tucker populations; rangers’ respectful engagement with Traditional Owners; the community’s respect for the work of the rangers, and community members having the opportunity to undertake burning practices.

3.3.4. Bush Tucker

Bush tucker, including edible plants and animals used for food that are sourced wild from the bush, was emphasised as important by most participants. The various resources utilised in different seasons were described and subsequently portrayed in the *Yugul Mangi Faiya En Sisen Kelenda*, the Roper River Kriol name for the Yugul Mangi Fire and Seasons Calendar (Figure 3.3).

Participants said that fire can impact on bush tucker by damaging and reducing the yield of native fruits or ground plants such as tubers. *‘Any tree that bears berry, we usually keep the fires away*

from them. Or do a small fire burn so when the hot fires come, it doesn't cook them. It is stopped by the firebreak that we make'—MR. Fire was said to be an important tool to protect and encourage growth of bush tucker resources. *'Burn-offs are important to keep our fruit, our shrubs, all the things that are in the bush that we use, for medicine or eating, so they can produce at the right time, especially with the berries and the yams'*—FE.

Many participants stressed the importance of careful burning around bush tucker plants, while some expressed concerns that burning too much, or at the wrong time, was having a detrimental impact on bush tucker abundance: *'Should not burn when there is still bush tucker available ... if you burn the grass early, you kill your own food, your own natural food'*—ME. *'Need to be careful about bush food. Too much burn-off makes less bush food'*—FE. Fire can also affect traditional animal food resources by reducing feed for prey animals, providing 'green pick' for herbivores or improving hunting conditions. *'Burning makes it easier to hunt animals including goanna, wallabies, kangaroos, bush turkey'*—MR.

Participants identified a number of impacts (other than fire) on bush-tucker production, including rainfall, feral animals, weeds and non-customary harvest of resources. *'We thought burning was interrupting the bush tucker but it is mainly feral animals. A little bit burning but mainly ferals. We are really concerned about this'*—FE. *'Most [bush-tucker production] depends on the rain, too; the past years we haven't had enough rain, that's why. The rain, the watering of our plants comes from the rain'*—FE. Protection and regeneration of bush tucker was important for ecological and cultural values, and closely linked to fire regimes: *'The burning and the bush tucker and the Country, it all comes together as normal practice ... if you burn the right way, you look after the bush tucker, the bush plants'*—MR.

3.3.5. Biocultural Indicators

We define biocultural indicators as predictable, obvious, seasonal events that are culturally significant. Nineteen participants shared knowledge of 40 biocultural indicators related to weather conditions, resource use, fire management and cultural and spiritual events. *'They have different flowering season for all the trees. Different animals that we can hunt for. So one group of trees, one species, that flowers during that certain month then we know which animals are ready to be hunted. Other trees flower then you know different animals ready to be hunted. All the trees finish flowering then we know wild honey time.'*—MR. Participants explained that some biocultural indicators are used as cues to initiate or cease certain fire management practices (Table 3.2, Figure 3.3). The rangers explained that reading Country and noticing biocultural indicators is important when

making decisions related to fire management: *'We look at the land first before we actually burn. What state is it in? Is it ready to be burning, or not? And you can tell that by the different colour on the grasses. If it's brown enough, yeah well, it's good. And then if it's too green, we might have to miss a month'*—MR. *'They [old people] used to know when to burn and then when it comes like this now, this season. May, that's when they start off. We knew that cold weather coming up. Cold weather and we know when you already burnt and that dew and fog going to come ... Green grass, new leaves and what we eat from the bush, like berries, plum and then the animals too, they follow where the best feed is. And then we know'*—MR.

Table 3-2 Yugul Mangi seasons, biocultural indicators and fire management practices.

Season, including Indigenous language names *	Weather conditions ⁺	Ranger and Elder observations & fire management	Examples of biocultural indicators	Savanna burning practices
Wet season (approximately December to March) <i>Reintaim</i> (Kriol, P1) <i>A-nyalk</i> (Ngandi, N90) <i>Agalhal-anbana</i> (Wubuy [Nunggubuyu], N128) <i>Dhuluḍur</i> (Ritharrŋu, N104, Wägilak, 106) <i>Mijal</i> (Marra, N112)	Mean rainfall 132–183 mm/month. Mean maximum temperature 34–38°C. Mean wind speed (9 am) 5.2–5.5 km/hr, (3 pm) 8.4–10.4 km/hr. Mean relative humidity (9 am) 65%–78%, (3 pm) 43%–57%	Too wet to burn. Rains every day, everything is green. How big the ‘wet’ (period of rainy weather) is depends on the amount of rain that falls	<i>‘Leichhardt’s grasshopper</i> [Petasida ephippigera], <i>he comes out with first storms’</i>—FE. <i>‘At the end of the Wet Season, knock ‘em down rain comes and the grasses point to the west. The spear grasses, wiyurlwiyurl, and other grasses drop their seeds’</i>—MR	Yugul Mangi rangers receive their final fire scar map for the year, review their burning, plan for next year and attend the ALFA meeting. They consult Traditional Owners and neighbours regarding their fire plans
Dry season (approximately April–August) <i>Kol wetha</i> (Kriol, P1) <i>Martdun</i> (Ngandi, N90) <i>Agalhal-mariga</i> (Wubuy [Nunggubuyu], N128) <i>Dharratharra</i> (Ritharrŋu, N104, Wägilak, 106) <i>Mardun</i> (Marra, N112) <i>Marluwuru</i> (Rembarrnga, N73)	Mean rainfall 1–56 mm/month. Mean maximum temperature 30–34°C. Mean wind speed (9 am) 5.2–7.1 km/hr, (3 pm) 11.8–14.1 km/hr. Mean relative humidity (9 am) 62%–74%, (3 pm) 29%–45%	Right time for burning. Cold weather, light south-easterly winds	<i>‘When you look at that dragonfly, he start flying, you know cold weather time’</i>—FE. <i>‘The whistling tree</i> [Casuarina spp.] <i>tells us cold weather is coming’</i>—ME. <i>‘Once the wind is blowing from the Gulf</i> [of Carpentaria], <i>south-east breeze, then we know it is time to burn’</i>—MR	Yugul Mangi rangers start cool burning (‘right-way’ burning). The rangers burn around outstations and prepare firebreaks with neighbouring pastoral stations. Fuel transport is undertaken to main camp for helicopter. From May to July, ground and aerial burning is undertaken. Yugul Mangi undertake monitoring at fire plots (several times after burn to check for new leaves, flowers, tree growth, grass and fuel loads) and use satellite technology to monitor fire scars

Season, including Indigenous language names *	Weather conditions*	Ranger and Elder observations & fire management	Examples of biocultural indicators	Savanna burning practices
Build up (approximately September to November) <i>Hotwetha (Kriol, P1)</i> <i>Warlirr-tdhi-na (Ngandi, N90)</i> <i>Agalhal-alirr (Wubuy [Nunggubuyu], N128)</i> <i>Midiwarr (Ritharrngu, N104, Wägilak, 106)</i>	Mean rainfall 2–42 mm/month. Mean maximum temperature 35–39°C. Mean wind speed (9 am) 6.2–6.9 km/hr, (3 pm) 11.8–16 km/hr. Mean relative humidity (9 am) 53%–59%, (3 pm) 25%–30%	'Nugudwan faiya' (Kriol for hot, destructive fire) time- wildfires. Dry, hot weather time	'Barra. <i>That's the hot wind that comes in from the north around August, September. That wind tells us the season is changing, you can feel the heat too, the humidity changes, and when it is hot that certain month, bang! Everything stops</i> '—MR. 'We traditionally finish burning in September, when we see the dark clouds come in, that's the build-up, we stop then'—MR. 'We know hot weather when we see that willy [whirlwind]... all the [magpie] geese [Anseranas semipalmata] they are fat now and it is right to go and hunt them'—FE.	Yugul Mangi rangers stop lighting large fires and start fighting hot fires. This time of year is 'wrong time fire'—it cooks everything, even small animals

* Indigenous language names for seasons are displayed as Language name for season (Indigenous language name and AIATSIS code, Australian Institute of Aboriginal and Torres Strait Islander Studies 2019).

* Source: Bureau of Meteorology (2019)

3.3.6. Use of the Fire and Seasons Calendar

Many participants agreed that the calendar would be useful for young people, community members, other ranger groups, researchers and the public. *'It is good for our young ones to know, our way of looking after the Country using fire. The calendar is the cycle of our ecosystem, the way we live and the way we hunt. Especially hunting and gathering food'*—MR. *'I think this calendar will be very, very useful for our children, to have them to learn about the different seasons and what is available during those seasons and most importantly, it is the burn-offs. What time the burn-offs should be done, that is the most important thing'*—FE.

Some participants felt that many people living in the SEAL IPA do not know how to burn properly, and need to be educated: *‘Some adults have been brought up—going away from here to colleges, schooling outside of here—and hardly getting the knowledge that they should about the land and what their land would provide at what times, so that’s important to all age groups’*—FE. They stated that the calendar could be used at ‘culture camps’ on Country to teach young people, while the plant and animal photos in the calendar could help Elders to remember stories to share. This could be followed up with experiential learning of fire management on Country: *‘We would like to use the fire and seasons calendar as part of our program, to get the kids connected on Country. To pass on knowledge about the environment and burning ... We want to educate our kids for early burning so they don’t do wrong way fire’*—FE. *‘Using paper, that’s a good help for the new generation, once they look at that and see what we’ve done, that’s our seasonal calendar they will think that’s what they do, on those months, until the end of the year. They don’t learn that in school. So what we do is we show the kids that and when they come out on culture camp, some of that will be in their head, “oh yeah I have seen that on the calendar chart”, they will say that, put it in black and white first to them and have that activity after, in real life’*—MR.

Rangers were enthusiastic to share the calendar with other Indigenous ranger groups: *‘I would love to show [the calendar] to the ALFA group at my next meeting. Even our annual fire meeting where all the ranger groups come together in one location and do our planning. Each ranger group presents what they will do for the year, what they have done last year, we can present that too at our annual fire meeting’*—MR. One ranger said that the calendar would be particularly meaningful as it had been developed by the Indigenous rangers with assistance from non-Indigenous scientists, rather than having been developed in isolation from the community: *‘This one [calendar], that’s the ranger group doing our seasonal chart with you [non-Indigenous scientist], making a lot of difference’*—MR.

3.4. Discussion

Our study has described a contemporary system of Indigenous burning of Country that uses Indigenous knowledge, traditional kinship systems and modern technology for best-practice, adaptive management of fire. The Indigenous Elders and rangers explained a fire management system that is based on intricate Traditional Ecological Knowledge (accumulated over thousands of generations of Indigenous people managing their clan estates, Berkes *et al.* 2000), local knowledge (of people living in and managing their environment on a day-to-day basis) and Western science. This combined knowledge, coupled with Indigenous fire practitioners’ ability to read Country and

identify biocultural indicators, places them in the unique position to be able to adaptively manage fire to meet their environmental, cultural and socio-economic objectives.

Non-Indigenous fire managers are sometimes constrained by government requirements to set burn dates based on the Gregorian calendar, coordination of resources and personnel from multiple agencies, and relying on suitable weather conditions on the set date. This means that agreements to burn are often obstructed by one or more of these factors and burning cannot proceed. In contrast, the Yugul Mangi rangers have more adaptability to match their burning practices to cultural Lore (through existing kinship and governance systems), the environmental conditions at the time, and can change their plans according to conditions. The Gregorian calendar, which is based on the Northern Hemisphere seasons of summer, autumn, spring and winter, translates poorly to Australia's seasonal conditions. In contrast, Indigenous peoples' seasonal knowledge is intimately related to their Country and suits the diversity of environments found in Australia.

For example, the *Yugul Mangi Faiya En Sisen Kelenda* (Figure 3.3) presented three seasons, given various names in traditional Indigenous languages, aligned to the annual cycle of fire management (Table 3.2). During the Wet Season, when it rains most days, it is too wet to burn, and an important time to collect bush-tucker fruits. The Dry Season is the right time to burn, when the weather is cool and there are light, south-easterly winds. Biocultural indicators are used to indicate when it is time to start burning, including the appearance of large numbers of dragonflies and the dominant savanna grass species dropping their seeds. This is an important time of transition, when the shrubs that fruited during the Wet Season finish fruiting, and burning should be carefully controlled around these important bush tucker resources. The Build-Up Season is a time of dry, hot weather, when fires have the potential to be larger, more intense and severe. This is the 'nugudwan faiya' (wildfire) time, when wildfires threaten to damage important ecological and cultural values. The biocultural indicators for the transition into the Build-Up Season are the arrival of hot winds, high temperatures and whirlwinds. This is an important time for harvesting magpie geese, freshwater shark and stingray. The rangers stop lighting fires during the Build-Up. The transition from the Build-Up to the Wet Season is marked by biocultural indicators including the appearance of Leichhardt's grasshopper with the first storms, the flowering of the whitewood (shark tree *Atalaya hemiglauca*), wattle (*Acacia* spp.) and paperbark trees, and crocodiles and turtles laying their eggs.

Using cross-cultural knowledge, such as that encapsulated in the *Yugul Mangi Faiya En Sisen Kelenda*, has enabled rangers to improve their fire management. Ansell and Evans (2019) found that in comparison to the baseline data (2000–14), during the registered years of the SEALFA2

project (2015–2018), fire management had improved in the SEAL IPA by reducing the total area that was burnt each year, shifting the seasonality of burning from late dry season to early dry season, increasing the patchiness of fires, increasing the area that was considered long unburnt, and reducing the GHG released from burning. This cross-cultural knowledge embraces the complexity of fire management, and allows rangers to make informed decisions for their burning practices. For example, as explained by a senior Yugul Mangi ranger, sometimes the helicopter is booked to burn a certain area of the SEAL IPA within the savanna burning timeframe, but if the grass has not yet turned from green to brown and dropped its seeds, it is not ready to burn, and the helicopter must be rescheduled. The information in the calendar can be also used to train new rangers through the transfer of knowledge contributed by senior rangers and Elders and to explain to external parties why savanna burning operations occur at given times throughout the year.

However, our study showed that there was still a range of views and tensions between Elders and rangers on ‘right way’ application of fire practices and a need for ongoing cultural education and fire awareness in the community. Fires were still occasionally lit late in the dry season which, along with wildfires, can damage ecological and cultural values. For example, participants described incidences where culturally important areas and bush tucker were burnt. Other concerns related to savanna burning were that SEALFA2 had not delivered a profit every year, and the focus on carbon and the use of Western tools challenged the balance between Western and traditional knowledge and practice. Similar concerns about the carbon economy have been raised by others in nearby Cape York (Martin 2013). This further highlights the need to strengthen and grow traditional cultural knowledge, practice, values and intergenerational exchange when adopting Western economies, tools and techniques.

In our study, the relationship between fire management and abundance of bush-tucker resources was highlighted as important, with declines in bush-tucker production an ongoing concern for the community. While fire was considered to be an important agent in the maintenance of bush-tucker resources, other impacts such as feral animals (buffalo [*Bubalus bubalis*], pig [*Sus scrofa*], horse [*Equus caballus*], wild cattle [*Bos taurus* and *B. indicus*]), climatic variation (rainfall), weeds and non-customary harvest were also identified. This correlates with findings by Ens *et al.* (2010) who investigated multiple causes of the decline of the bush-tucker fruit, Djutpi (Jupi, *Antidesma ghaesembilla*), in the SEAL IPA. Ongoing vigilance in protecting important bush-tucker resources from various threats and learning to adapt to new conditions and knowledge will be needed in order to maintain these culturally important resources.

The importance of improving Indigenous burning education and awareness for the community, particularly the younger generation, was consistently emphasised by participants. Participants were concerned that community members were not interested in learning about burning, did not have access to Country, or did not have mentors to learn the correct way to burn. We found that community awareness of the rangers' fire management, particularly savanna burning for GHG abatement, was low. The SEAL IPA Plan of Management (Gambold 2015) included the following intended actions: 'develop and run culture camps out on Country for children and young people' and 'run right-way Fire Workshops in early dry season for students and unemployed youth.' In 2019, 63% of SEALFA2 profits were planned to be used for ranger operations and 37% for community development, including culture camps (Northern Land Council 2019), training and facilitating Traditional Owner access to Country. As suggested by participants of this study, the fire and seasons calendar could be used as a teaching resource at these events, in schools and to improve community awareness of fire management.

3.5. Conclusions

Indigenous seasonal calendars from around the world have illustrated how Indigenous knowledge and connection to Country provide a deep and intimate understanding of the landscape. The *Yugul Mangi Faiya En Sisen Kelenda* adds to this growing collection, and aims to improve the evolving fire management practices of Indigenous land managers, while also providing an effective communication tool to increase awareness of Indigenous savanna burning. While Prober *et al.* (2011) lamented that seasonal knowledge is not yet well embedded in natural resource management and recommended investigation of how its applications might be improved, we have demonstrated a way in which a seasonal calendar can be used for multiple purposes.

Savanna burning has provided Indigenous peoples with the economic support to care for Country through the fundamental practice of fire management. Globally, recognition of Indigenous knowledge and management of fire is growing, but real action on policy and on ground works is limited (United Nations 2019a). The Yugul Mangi rangers are an example of an Indigenous group who have transcended the barriers to Indigenous leadership in fire management. Documenting their local and Traditional Ecological Knowledge through the *Yugul Mangi Faiya En Sisen Kelenda* has allowed them to share their knowledge and explain their world-view related to fire management. Many Indigenous groups around the world aspire to increase their participation in fire management and have their knowledge recognised and appreciated (Cramer 2019). We recommend the development of fire and seasons calendars as a practical and educational activity that could be

relevant to many of these communities and help avoid potential misunderstandings between Indigenous and non-Indigenous fire managers. This could drive an increase in the uptake of adaptive and locally attuned Indigenous fire management to alleviate poverty, cherish Indigenous knowledge, fight climate change and restore ecosystems in many locations across the globe.

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STATEMENT OF AUTHORS' CONTRIBUTION

We, the PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated in the *Statement of Originality*.

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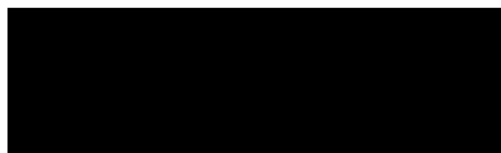
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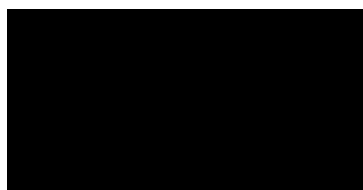
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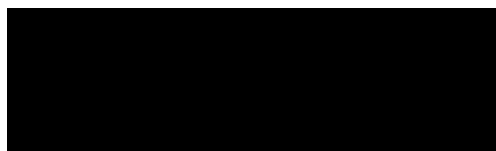
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Chapter 4. Cross-cultural monitoring of a cultural keystone species informs revival of Indigenous burning of Country in south-eastern Australia

Title of Article:

‘Cross-cultural monitoring of a cultural keystone species informs revival of Indigenous burning of Country in south-eastern Australia’

Authors: Michelle B. McKemey, Maureen (Lesley) Patterson, Banbai Rangers, Emilie J. Ens, Nick C. H. Reid, John T. Hunter, Oliver Costello, Malcolm Ridges and Cara Miller

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4.0. Abstract

Globally, Indigenous cultural burning has been practiced for millennia, although colonisation limited Indigenous people's ability to access and manage their ancestral lands. Recently, recognition of Indigenous fire management has been increasing, leading to the re-emergence of cultural burning in Australia, the Americas, parts of Asia and Africa. We describe how the Banbai people of south-eastern Australia have reintroduced cultural burning at Wattleridge Indigenous Protected Area. Our team of Banbai rangers and non-Indigenous scientists conducted cross-cultural research to investigate the impact of burning on a cultural keystone species, the Short-beaked echidna (*Tachyglossus aculeatus*). Our comparison of the effects of a low-intensity, patchy, cultural fire in the Wattleridge Indigenous Protected Area to a nearby higher intensity fire in Warra National Park through a Before-After-Control-Impact assessment indicated that the higher intensity fire reduced echidna foraging activity, possibly to avoid predation. Most importantly, we describe a cross-cultural research model whereby Indigenous rangers and non-Indigenous scientists work together to inform adaptive natural and cultural resource management. Such trans-disciplinary and collaborative research strengthens informed conservation decision-making and the social-ecological resilience of communities.

Key words: Indigenous knowledge, Traditional ecological knowledge, Indigenous fire management, Protected area management, Cultural keystone species, Short-beaked echidna (*Tachyglossus aculeatus*), The Banbai Aboriginal Nation, South-eastern Australia.

4.1. Introduction

Globally, inclusion of Indigenous peoples and their knowledge in conservation planning is increasing, as evidenced by the Aichi Targets of the Convention on Biological Diversity (Secretariat of the Convention on Biological Diversity 2014) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES Secretariat 2019). Australia's central piece of environmental legislation, the *Environment Protection and Biodiversity Conservation Act 1999* (Cth), mandates the involvement of Indigenous peoples in conserving Australia's biodiversity, recognising the role of Indigenous peoples in the conservation and sustainable use of resources, and promotion of traditional knowledge to inform management and conservation decisions (Hawke 2009). Integration of Indigenous knowledge and Western science has been advocated and conducted for decades (Agrawal 1995; Berkes 1999; Young 1999; Huntington 2000) to inform environmental management. Such cross-cultural knowledge can enhance understanding of the complexity and uncertainty in social-ecological systems (Folke *et al.* 2005) while building resilience and flexibility in response to changing environmental and social contexts (Redman and Kinzig 2003; Bohensky and Maru 2011).

Increased recognition of the value of Indigenous knowledge and practice in fire management, has led to community-based and integrated fire management projects in southern Africa, Brazil, and northern Australia (Moura *et al.* 2019). Countries such as India (Thekaekara *et al.* 2017), Indonesia (Russell-Smith *et al.* 2007a), Canada (Miller and Davidson-Hunt 2010), the U.S.A. (Armatas *et al.* 2016; Lake *et al.* 2017), Venezuela (Eloy *et al.* 2019a), and Guyana (Mistry *et al.* 2016) have been called on to institutionalise and implement similar policies and practices that involve Indigenous knowledge and people.

In Australia, Indigenous peoples' rights and interests in land are formally recognised over 40% of Australia's land surface (Department of Prime Minister and Cabinet 2018). Indigenous Protected Areas (IPAs) cover approximately one hundred million hectares, comprising 54% of Australia's National Reserve System (Department of Environment and Energy 2019). Indigenous peoples have inhabited Australia for over 65,000 years (Clarkson *et al.* 2017) and practiced fire management (Bowman *et al.* 2012) across many biomes including desert (Latz 1982; Kimber 1983), savanna (Yibarbuk *et al.* 2001), and rainforest-grass patches in Tasmania (Bowman *et al.* 2013). Traditionally, Indigenous burning was used to procure food and medicine, provide access to resources, clear pathways for travel, signal to other groups, and for warmth, cooking, safety, and spiritual purposes (Kohen 1996; Pascoe 2014; Cahir *et al.* 2016). Following European colonisation

of Australia in 1788, many traditional practices were prohibited and Indigenous people were variably coerced to leave or removed from their lands (Blomfield 1992; Elder 2003). The post-colonial disruption of traditional Indigenous fire regimes is considered one of the major causes for Australia's extraordinary number of mammal extinctions (Woinarski *et al.* 2015).

In northern Australia over the last decade, traditional Indigenous fire practices have been re-ignited to reconnect people to Country and culture, and concomitantly support economic development and enhanced land management. For example, the Savanna Fire Management initiative (Commonwealth of Australia 2018) served to reinstate traditional burning practices of small patchy fires to replace the large hot wildfires that resulted from the post-colonial depopulation of Indigenous people from Country (Moura *et al.* 2019), although deployment of traditional practices has been debated (see Martin 2013). The greenhouse gas abatement program that resulted has provided much needed income to Indigenous land managers who aspire to live and work on their ancestral estates in northern Australia (Russell-Smith *et al.* 2009).

Conversely, in south-eastern Australia fire is primarily managed by government agencies for the protection of life and property (Office of Environment and Heritage 2013) and few Indigenous-led burning programs exist (Maclean *et al.* 2018). In recent years there has been a revival of interest in Indigenous cultural burning in south-eastern Australia in response to the successes of Indigenous fire management in the north and to similarly re-connect people to Country (Office of Environment and Heritage 2016; Firesticks Alliance 2020; Neale *et al.* 2019). In response to the groundswell of Indigenous community interest in cultural burning, governments are rapidly co-developing policies in support, such as The Victorian Traditional Owner Cultural Fire Strategy (The Victorian Traditional Owner Cultural Fire Knowledge Group 2019). However, on the ground, substantial barriers (such as funding and legal constraints) often limit the involvement of Indigenous people in fire management of south-eastern Australia (Smith *et al.* 2018). Additionally, there are few data to demonstrate the outcomes of cultural burning in this region, from both scientific and cultural standpoints.

Our research was designed to address this gap by using a collaborative approach. Cross-cultural (or two-way) techniques are described as 'using combinations of Indigenous and non-Indigenous knowledge and methods and with the involvement of both Indigenous and non-Indigenous people towards a common goal' (Ens 2012: 46; Ens *et al.* 2012; Hoffmann *et al.* 2012; Walsh *et al.* 2013; Ens *et al.* 2015; Zanotti and Palomino-Schalscha 2016). Therefore, we aimed to use cross-cultural science to monitor the impact of cultural burning on the culturally significant short-beaked echidna

(*Tachyglossus aculeatus*, referred to henceforth as ‘echidna’). We compared the impact on echidnas of Indigenous-led mosaic (patch) burning at Wattleridge IPA (managed by the Banbai rangers) to a comparatively large hazard reduction fire undertaken by the New South Wales (NSW) National Parks and Wildlife Service (NPWS) at nearby Warra National Park (NP). Both are considered the Indigenous Banbai people’s Country.

Garibaldi and Turner (2004) defined cultural keystone species as ‘culturally salient species that shape in a major way the cultural identity of a people. Their importance is reflected in the fundamental roles these species play in diet, materials, medicine, and/or spiritual practices.’ The echidna has long been a valued food and medicine source, subject of cultural stories, and bio-cultural indicator for many Indigenous communities throughout Australia. At Wattleridge IPA, the echidna features in rock art, is a totem for many of the Banbai rangers, is one of the few animals for which a name is known in the Banbai region (‘kukra’), and is an iconic animal, symbolising the Banbai people. Historical records list the Banbai ‘tribal’ name as meaning ‘porcupine (echidna) cooking all the time’ (MacPherson 1930 in Sonter 2018: 16). For these reasons, we consider the echidna to be a cultural keystone species for the Banbai people. Garibaldi and Turner (2004) suggested that the identification of cultural keystone species provides an effective and highly beneficial starting point for conservation and restoration of social–ecological systems. However, practical methods for monitoring cultural keystone species are not always readily available and judicious application of such methods is imperative.

The echidna is one of only five extant species of monotreme and is the most widespread native mammal in Australia, occupying diverse habitats from the tropics to the arid centre (Augee *et al.* 2006). The echidna’s mean home-range size is approximately 48 ha (female) to 107 ha (male), although this varies according to region (Nicol *et al.* 2011). In the study region, the main food sources of the echidna are ants, scarab beetle larvae, and termites. Echidna habitat use and selection is primarily constrained by availability of shelter and secondarily by food (Smith *et al.* 1989). Fire may impact on echidnas through mortality, by inducing or interrupting torpor (Nowack *et al.* 2016), affecting food availability (York 1996; Croft *et al.* 2010), decreasing key habitat features such as hollow logs, trees and stumps, leaf litter and thick undergrowth (Augee *et al.* 2006), and increasing vulnerability to predation (Hradsky *et al.* 2017).

In this study, we investigate and describe the reintroduction of cultural burning and the cultural significance of the echidna to the Banbai people. We used cross-cultural methods to assess how echidnas responded to low-intensity Indigenous-led mosaic burns and moderate intensity

government-led burns. Through interviews with Banbai people, we also aimed to explore the implications of this research for future fire and conservation management. Finally, we consider the broader potential applications of collaborative cross-cultural approaches to strengthen local social–ecological knowledge for more inclusive conservation decision-making.

4.2. Methods

4.2.1. Study Site

Located in the New England Tablelands of New South Wales (NSW), the Banbai Aboriginal Nation is relatively small, covering a land area of 6000 km² (Tindale 1974). Currently, the Banbai language group 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 Sonter (2018: 31) suggested ‘the rapid displacement of the Banbai people from their home lands during the 19th century and the advent of agriculture prevented traditional burning, hunting and gathering cultural practices.’ The Wattleridge IPA (480 ha) was voluntarily declared an IPA in 2001 and is owned and managed by the Banbai Aboriginal Nation (Fig. 4.1) for the conservation of biodiversity and Indigenous cultural heritage (Patterson and Hunt 2012). From 2009, the Banbai rangers started to re-learn cultural burning practices through engagement with Indigenous fire specialists (George 2013), other Indigenous ranger groups, and the Firesticks Project (Firesticks Project 2017). Assistance was also provided from government agencies such as the Rural Fire Service (RFS).

4.2.2. Socio-Cultural Research

We adopted an inductive approach to our qualitative sociocultural research using participatory action research and semi-structured interviews (Babbie 2013). For the participatory action research, a non-Indigenous scientist (MM) and the Banbai Indigenous rangers participated in two activities: implementing a cultural burn and monitoring echidna activity before and after the burn. Semi-structured interviews were recorded audio-visually and then transcribed, and were organised around the themes of cultural burning, significance of the echidna, impact of fire on echidna activity, and collaborative monitoring (Appendix 4.1).

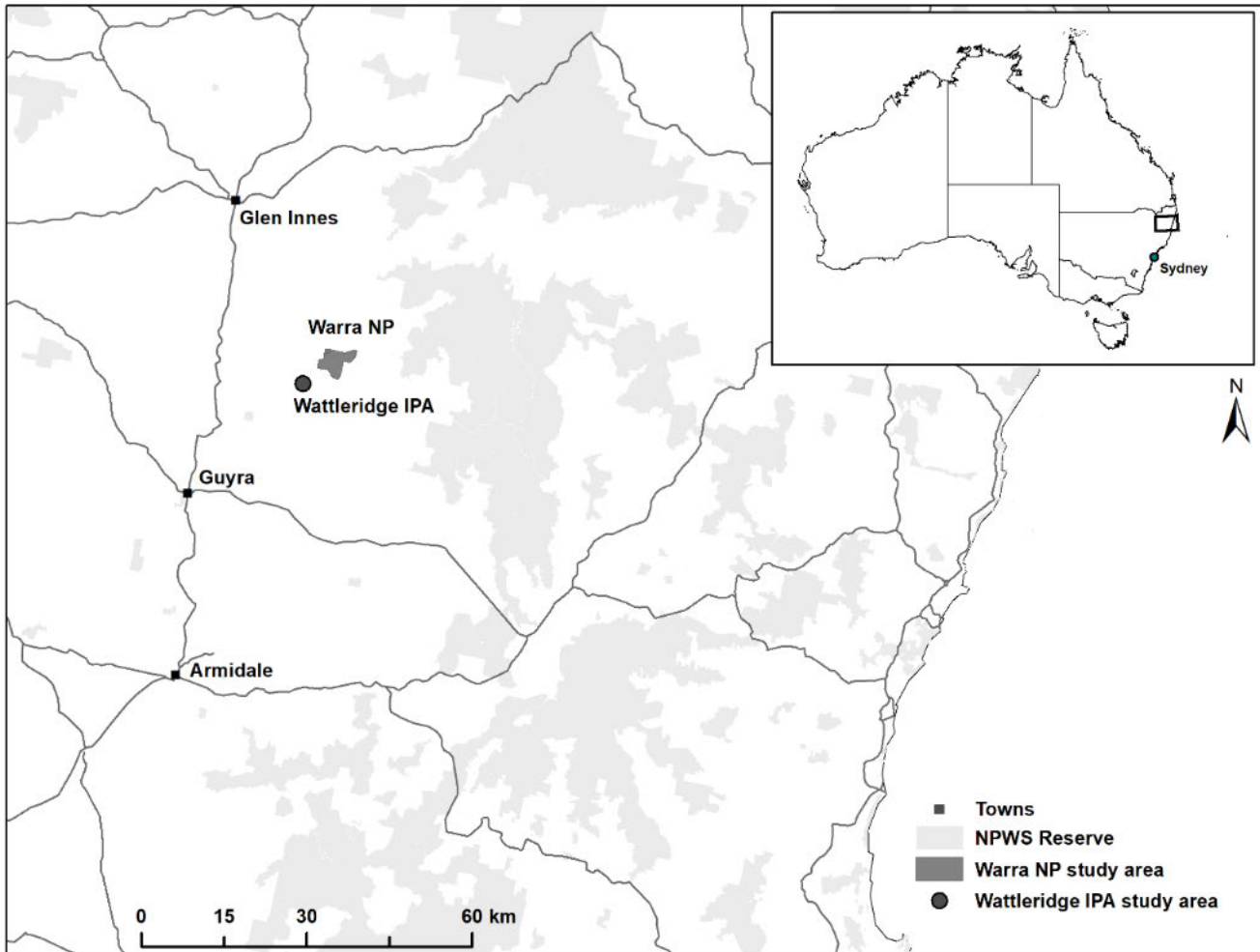


Figure 4-1 Location of the study areas (Wattleridge Indigenous Protected Area and Warra National Park) in northern New South Wales, Australia.

Nine Banbai were interviewed (Table 4.1). Eight were rangers with more than six years' experience; two were female and three were considered Elders. Five Banbai were interviewed prior to the planned burn in 2015, four during the burn and six after the burn. Eight rangers (including two Elders who were also rangers) participated in data collection and monitoring echidna activity. The participation of rangers depended on their availability and willingness to be interviewed. Interview results were coded a posteriori in NVivo and grouped into themes (Schwandt 2014).

Table 4-1 Participants in semi-structured interview research.

Ranger	Gender	Role in Banbai group	Ranger experience
TE	Female	Elder & manager	10+ years
LP	Female	Elder & ranger	10+ years
MT	Male	Elder & ranger	6 years
TP	Male	Ranger supervisor	8 years
KP	Male	Ranger	6 years
CP	Male	Ranger supervisor	8 years
DC	Male	Ranger	10 years
TrP	Male	Ranger	10 years
DP	Male	Ranger	10 years

4.2.3. Collaborative Ecological Monitoring

We undertook a collaborative ecological monitoring program pre- and post-burn based on a Before-After-Control-Impact (BACI) experimental design (Underwood 1991). Two planned burns were undertaken in 2015:

1. A small (4 ha) low-intensity mosaic burn on 16/08/2015 by the Banbai rangers (with RFS present) at Wattleridge IPA. Time since the last fire was approximately 30 years (Rural Fire Service NSW, 2015).
2. A large (685 ha) moderate-intensity burn on 20/10/2015 by NPWS and RFS at Warra NP and adjoining private land. The planned burn area was 351 ha; however, another fire started nearby and met with the planned burn to increase the total burnt area to 685 ha. Time since the last fire was 16 years (National Parks and Wildlife Service NSW, 2015).

Prior to each fire, 30 monitoring plots were established across the two study sites (12 at Wattleridge IPA, 18 at Warra NP). Following the BACI design, 15 each of the control and impact plots were measured twice, before (2015, all plots unburned) and after (2016, control plots remained unburned) fire. Control and impact plots shared vegetation type, soil, geology, climate, slope, aspect, and location (Hunter 2005). Plots were stratified within community types and randomly placed in each zone. Plots at Wattleridge IPA and Warra NP were allocated throughout an area of

20 ha at each location. Plot dimensions were 20 m× 50 m (large plot) and each plot included one nested plot of 20 m² (small plot) as described by the Department of Environment Climate Change and Water (2011).

The Banbai rangers and a non-Indigenous scientist (MM) undertook collaborative monitoring in each large plot. Before (2015) and after (2016) fire the team measured total log length (as per Department of Environment Climate Change and Water 2011), litter depth (as per Hines *et al.* (2010), and the number (count) and area of echidna signs (by measuring length and breadth of litter rakings and soil, log, and mound diggings, as per Smith *et al.* 1989). Following the fires, the fire-intensity rank of each fire (fire rank) was determined based on fire plans, size (National Parks and Wildlife Service NSW, 2015; Rural Fire Service NSW, 2015), observed intensity, proportion of each plot burnt, fire scar height, and change to overall fuel hazard (Hines *et al.* 2010; McStephen 2014). We analysed four response variables (count and area of echidna signs, litter depth, and log length per plot) in relation to fire activity (before vs after) and plot type (control vs impact) with R statistical software (R Core Team 2017). We examined the two locations (WNP and WR) separately. Inspection of model deviance and dispersion in various models led to the selection of a negative binomial generalised linear model (GLM) for modelling count data. ANOVA model assumptions of normality of residuals and heterogeneity of variances were satisfied. We ran two-way ANOVA models on the three other response variables (echidna area, litter depth, and log length) using this approach. A paired t-test was conducted in Excel, comparing the area of echidna signs in impact plots at Warra NP before and after fire, after removing one large outlier value from the ‘before’ data.

4.3. Results

4.3.1. The Meaning of Cultural Burning to Banbai People

Prior to 2009, the Banbai rangers did not have the opportunity to participate in fire management on their land and they acknowledged that there were gaps in their knowledge regarding the application of traditional Indigenous burning techniques in the temperate tablelands environment they manage as the Wattleridge IPA. In order to re-learn and apply Indigenous burning techniques the Banbai rangers invited Indigenous fire specialists to their Country to facilitate the revival of cultural processes and assist the Banbai people to rebuild cultural knowledge and practice. These processes were led by local Indigenous custodians and their cultural mentors and applied in a local context that supported the culture, identity, and ecology of Wattleridge IPA, in a manner similar to

traditional Indigenous knowledge transmission. This shared cultural knowledge was developed through engagement with Elders, 'reading Country,' and burning in many landscapes with Indigenous communities across Australia. As the rangers explained:

'Until 2009, we didn't do any cultural burning at Wattleridge IPA 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. 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 fire out, and to have respect for it. She used to burn every year ... Fire is a good tool but it can also be destructive, and knowing how to work with fire 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.' [LP].

'The thing with our community is there are not many Elders left in our community. They do hold a lot of knowledge but a lot of it was lost and I think it wasn't really taught how to burn properly ... So that is why we ventured off to different communities and asked them, what are your purposes for burning? How do you burn and why do you burn? So we took that back to our community and got the Elders involved, so that is a real learning curve for them and also for us, to keep that knowledge going is one of our key things that we need to do, to administer it in schools and to get our young fellas up and bringing them out and using fire the safe way to manage property, not just lighting it and expecting it to burn.' [TP].

'We have been doing traditional burns. [A cultural burning practitioner] came down and showed us the traditional way. We lost a lot of Elders and back in the day, they wasn't allowed to teach us anything. So he came down and gave us back some sort of power, we can do that and we know the right way of doing it ... As I get older I will teach my grandchildren how to burn and pass it on that way.' [LP].

KP described the intention of the cultural burn undertaken for this study:

'The objective of the fire was ... to see how the echidna goes, before and after fire... And just so if we do have wildfires, it just doesn't come rushing into the protected area...' [KP].

After the cultural burn, KP described the low-intensity mosaic nature of the cultural burn:

'The difference to the way we burn is ... we set it up so it's not just gonna fly for the bush. And so we just slowly move through the bush and not everyone is just going through to burn everything ... A wildfire would just kill everything and start ground fires, so we just try to keep it low.' [KP].

4.3.2. Cultural Significance of the Echidna to Banbai People

Interviews with the Banbai rangers confirmed that the echidna fits the criteria established by Garibaldi and Turner (2004) for a cultural keystone species, including: use; naming in language and use as a seasonal indicator; symbolism; memory of use in relationship to cultural change, and extent to which it can be replaced. Furthermore, echidna activity was easy to monitor through distinctive signs, so it was selected for monitoring in this preliminary study:

'We picked the echidna because it is very significant to us, it is on our logos and it is also on the art site cave... The echidna was eaten by our people unless it was your totem, you couldn't eat your totem but it was definitely a food source and a medicine, good nutrients from the fat and the meat... still eaten today.' [TP].

Banbai Elder and co-author LP described the changing use of the echidna over time. In some areas of Australia the echidna remains an important food source and detailed Indigenous knowledge regarding its preparation is maintained. As Wattleridge IPA is now a conservation area, the echidna is regarded as an important species to protect:

'The kukra is important because it is a symbol of who we are. We are in this big nation of Aboriginal people all over Australia. In parts of Australia it is telling us where we belong, it is our identification ... Growing up as a kid, I only ate [the echidna]. I knew... the best way to cook him and quill him. Becoming an adult and Aboriginal ranger I have learnt so much more about the echidna and you need to protect it.' [LP].

4.3.3. Indigenous Monitoring of Echidna and Fire Impacts

Some of the Banbai rangers live at Wattleridge IPA and the remaining rangers visit the IPA several times per week. This gave them the opportunity to use their local knowledge and tracking abilities to observe echidna activity before and after the fires:

'What we've got here, it is an echidna digging and these are some of the things that we're looking for before and after the burn to see how more active they are before and after...It's probably only a day-old digging...but you know that there's a few in the area.' [TP].

'Before and after the burn there was a fair bit of activity with the echidna...after the burn they didn't have to dig as deep to get to the ant or the grub or the termite, you noticed on some of the ant mounds, the echidna would dig through the ant mound and get them all out so there's all these details we took advantage of when observing them and checking their diggings ... The fire opened up the Country to the echidna finding the food source easier. I think he don't have to scrounge around under logs and thicker area where he can go along and see along there and don't have to put in enough effort to get the feed, he can just come along after you've burnt the Country and eat what he's got and it's easier for him to find his food source, I think that's one of the things he would thank us for.' [TP].

'It [echidna] was active straight after the fire, you'd drive past and see them walking around... they move around in clear areas feeding.' [KP].

4.3.4. Benefits of Indigenous Cultural Burning

Rangers agreed that frequent small low-intensity fires would benefit the echidna, reduce the risk of destructive wildfires, and maintain important habitat features. They expressed enthusiasm in continuing to learn and apply cultural burning practices:

'We should definitely burn more I would say ... the echidna gets out and about more after the fire so hopefully that increases them.' [CP].

'Cold, mosaic burns are best ... the ones that don't come through and burn everything out like logs and all that, open them up for predators so definitely low burns and cool burns.' [KP].

'So you are not burning everything out so you can give other things, like insects, their home. There are a lot of things that live under the surface and if you burn all that out you are burning them out as well so that is one of the reasons why we use the low intensity burn so we are not burning everything out of the Country.' [TP].

'We leave behind hollow logs so they [echidnas] can get into them.' [CP].

4.3.5. Western Scientific Assessment of Effects of Fire on Echidna Activity

4.3.5.1. Fire Rank

All impact plots at Warra NP were given a moderate fire rank, while all impact plots at Wattleridge IPA were given a low fire rank (Table 4.2). The fire at Wattleridge IPA decreased the fuel load, resulted in lower tree fire scars, and was more patchy and lower in total size than that at Warra NP.

Table 4-2 Fire measurements (mean $\pm$ SE, sample size in parentheses) and rank in impact plots at Wattleridge IPA and Warra NP.

Indicator	Wattleridge IPA	Warra NP
Mean fuel load decrease (t/ha)	8.9 $\pm$ 1.08 (6)	7.8 $\pm$ 0.88 (9)
Mean fire scar height (m)	3.8 $\pm$ 0.65 (6)	5.8 $\pm$ 1.25 (9)
Mean proportion plot burnt (%)	59 $\pm$ 8.0 (6)	81 $\pm$ 5.1 (9)
Total fire size (ha)	4	685
Fire plan intensity	Low	Moderate-high
Observed intensity	Low	Moderate
Fire rank	Low	Moderate

4.3.5.2. Counts and Area of Echidna Signs

The count of echidna signs increased in both control and impact plots after the fire at Warra NP ($p = 0.002$) (Fig. 4.2a). The area of echidna signs decreased in the impact plots after fire at Warra NP ($p = 0.036$) (Fig. 4.2b).

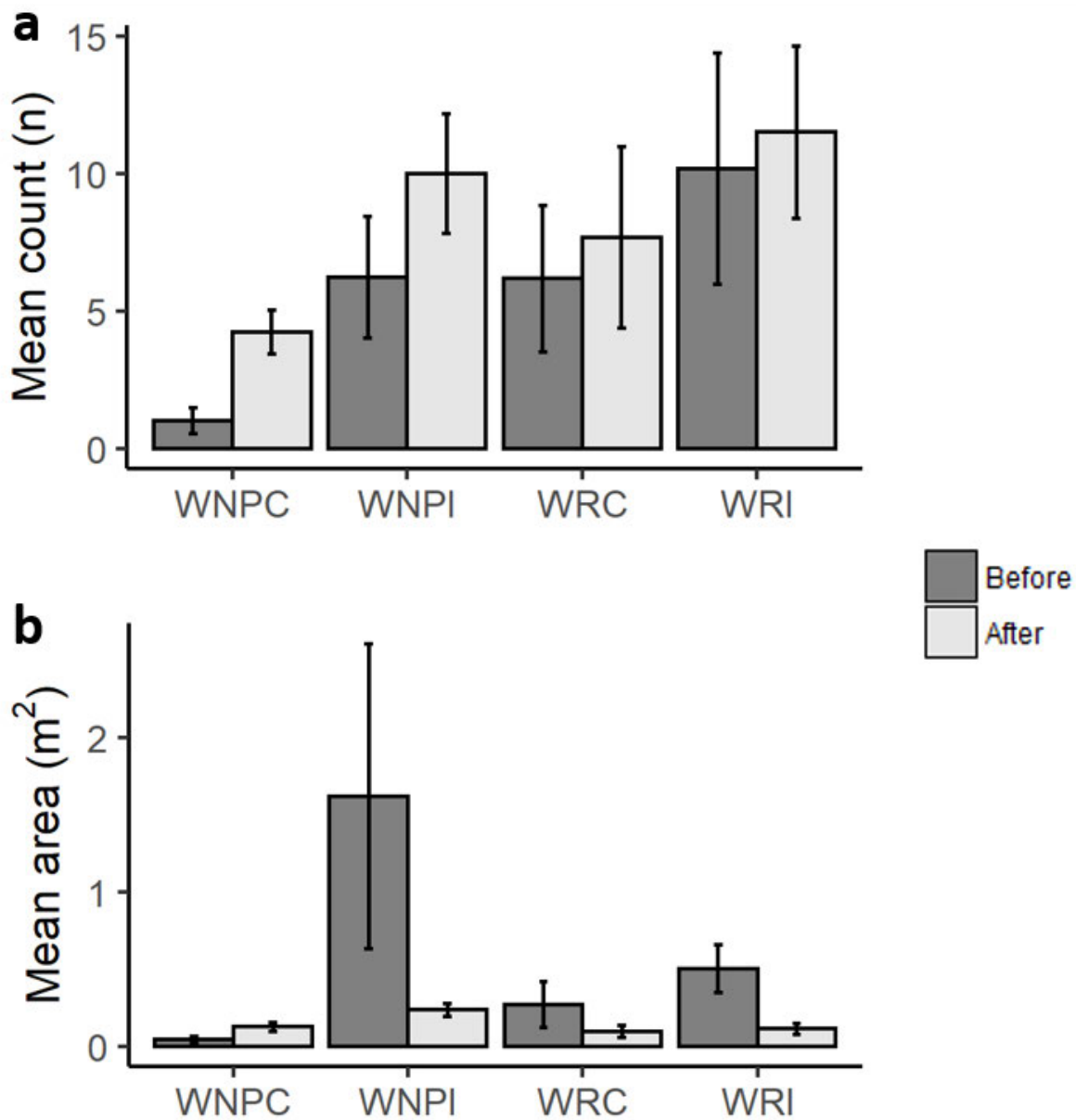


Figure 4-2 Mean count (n) (a) and area (m²) (b) of echidna signs before and after fire at control (C) and impact (I) plots at Warra NP (WNP) and Wattleridge IPA (WR).

4.3.5.3. Leaf Litter Depth and Log Length

Litter depth in impact plots at Warra NP declined after fire ($p = 0.033$) (Fig. 4.3a). There was no significant change in log length at the control and impact plots before and after the fires at Warra NP ($p = 0.596$) and Wattleridge IPA ($p = 0.730$) (Fig. 4.3b).

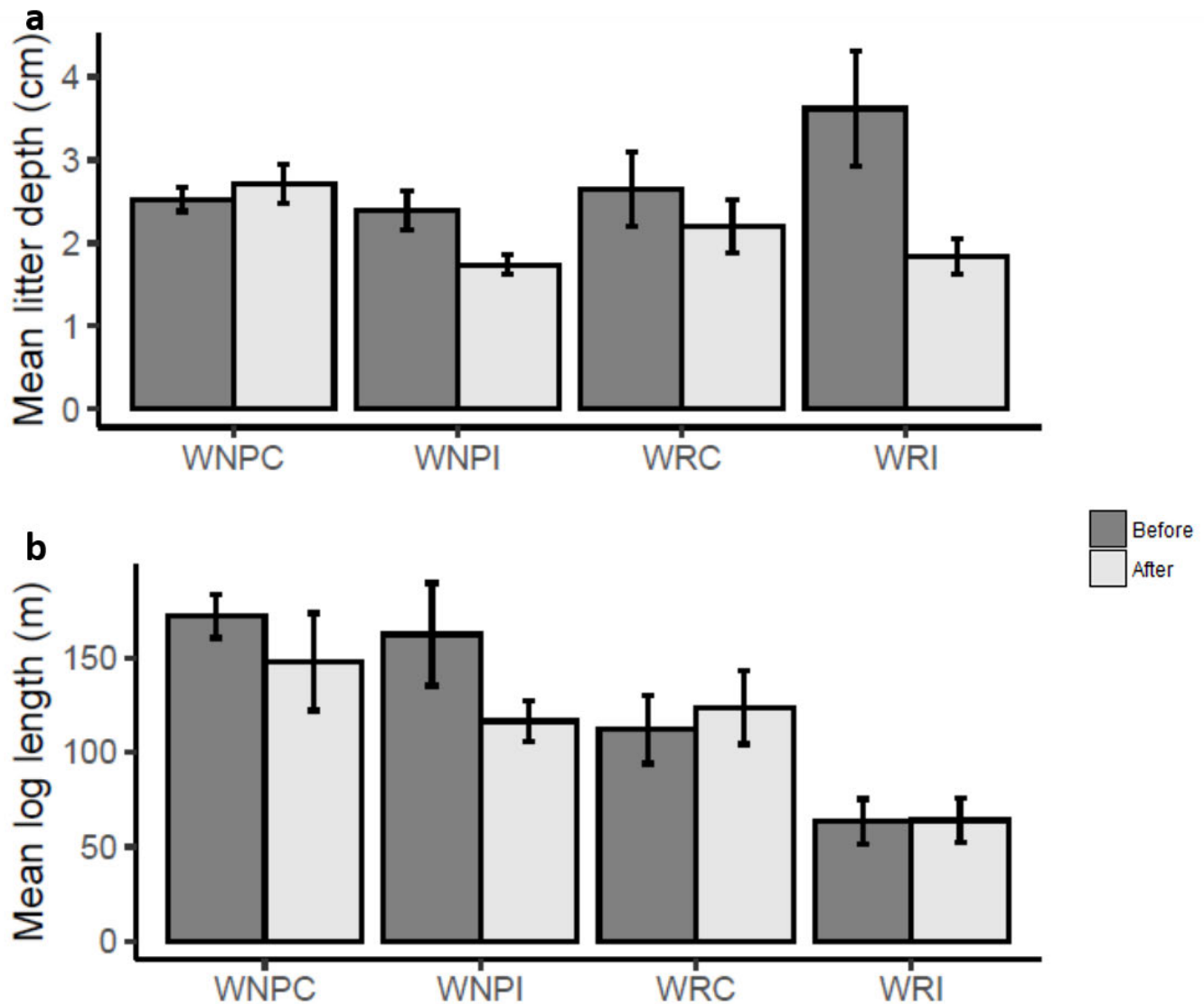


Figure 4-3 Mean leaf litter depth (cm) (a) and log length (m) (b) before and after fire at control (C) and impact (I) plots at Warra NP (WNP) and Wattleridge IPA (WR).

4.3.6. Using Cross-Cultural Science to Improve Ecological and Cultural Outcomes

The Banbai rangers stated that they benefited from the cross-cultural research in a variety of ways, including: conservation of echidna through appropriate fire management; developing skills and knowledge for rangers; and facilitating intergenerational transmission of cultural knowledge:

'We can use this research to monitor the echidna with fire in terms of don't come through and just burn everything out. We can use that because the echidna is such a significant thing to us.' [KP].

'[This research] will give the junior rangers and new rangers that start to know how to recognise the diggings... I would like to see more kids out on Country, that way if you start out with one thing maybe years down the track they are going to pick up one more thing and one more thing, by the time they become an adult they have a lot of things. That way they can pass it on. I think and more advanced, something where they can pass on, not where they have got nothing. At least with knowledge you can pass it on.' [LP].

Rangers agreed unanimously that they would like to continue to monitor important plants and animals to learn more about the biodiversity values of Wattleridge IPA and how various species respond to fire:

'We would definitely like to do more work like this— definitely put more burns in...If we can manage to look after these animals and bring them back in, that will make the Country a lot healthier and definitely, keep monitoring them and record them.' [TP].

On average, five rangers rated the amount of information learned through the echidna-monitoring project as 9 out of 10. Rangers were confident that they could continue the monitoring program independently:

'I didn't really know much about the echidna or fire burns per se and that has really opened our eyes as to how we can manage our Country and look after the animals in the area, that is what our people have been doing for thousands of years so to bring that back to Country that is really significant to us and to see the results that have come back from fire and not only that, the help that we have had to administer the fire and the knowledge that we was given to help do it, it is really an eye opener for all of us ... I think we could definitely continue to monitor the echidna ourselves. I think all of the information we have gathered ... and all the people who have helped us and given us that cultural knowledge to help look after the echidna and monitor that, I think that is the first

stepping stone to us helping the other animals to get back to their natural state and bringing more of them back to Country and bringing people out to show them the things we have done, all of the processes we needed to do and the help that we had, so yeah, definitely.’ [TP].

4.3.7. The Importance of Looking after Country and Culture

The Banbai rangers identified culture as a key driver in their land management aspirations, and described the process of cultural revitalisation through caring for Country:

‘For me personally it is getting back to Country and learning culture and I think it fills a void in yourself to know, to want to do it more, and to not only learn it but to keep that knowledge going, to teach it to our children for generations and get that cultural, spiritual aspect to ourselves and to our Country. Like they say, the Earth is our mother, we have to look after her.’ [TP].

‘I think a lot of it is to do with trying to help the land and keep it for generations to come and I think some of the stuff we know we can teach kids and we are just going to keep growing our knowledge and we are just going to carry it all on. It’s something we never really grew up with. I think it is important for us to pick it up and keep it going.’ [KP].

‘It is something that was never ever taught. Teach the kids and the younger generation.’ [MT].

4.4. Discussion

Many decades after being displaced from their ancestral lands, the Banbai people have, for the first time, been empowered to reintroduce cultural burning at Wattleridge IPA. Banbai rangers expressed their purposes for undertaking cultural burning: to relearn an ancient cultural practice, develop and pass on knowledge to future generations, connect to Country, make Country healthy, protect habitat, manage fire safely, and monitor and conserve the echidna. Following the fire at Wattleridge IPA, the Banbai rangers observed that the fire was low-intensity, slow and patchy; that the fire didn’t burn out key echidna habitat requirements such as logs, which provide protection from predators, and that the fire made it easier for the echidna to find food. The Western scientific assessment found that the government-led moderate-intensity fire at Warra NP affected the activity of echidna and changed the availability of key habitat resources, whilst the differences recorded after the low-intensity fire at Wattleridge were not statistically significant. After the Warra NP fire, echidna activity increased but the area of echidna signs decreased. Leaf litter decreased significantly in the moderate-intensity burnt plots at Warra NP but not in the low-intensity burnt plots at Wattleridge IPA. Ants, the main food source of the echidna, increase in abundance in burnt

areas after fire (York 1996; Croft *et al.* 2010), as do predators, which increase their consumption of echidna (Hradsky *et al.* 2017). In general, the Indigenous and Western scientific knowledge systems concurred, finding that the lower intensity burn at Wattleridge IPA did not significantly impact on echidna activity and key habitat resources.

Research participants were interested to learn how the higher intensity fire at Warra NP affected the echidna. The change in echidna activity at Warra NP could be due to echidnas moving through burnt areas more rapidly (feeding on the abundant ants but moving on without protracted foraging through logs and litter) in order to reduce vulnerability to predation. The fire at Warra NP was much larger (685 ha) than the Wattleridge IPA fire (4 ha), so the interaction of home range and burnt areas may have affected foraging behaviour of echidnas post-fire. For example, the Wattleridge IPA low-intensity fire only burnt the equivalent of 8% of a single female echidna's home range, whereas the Warra NP fire potentially covered the equivalent of the whole range of 14 female echidnas. After the fire, a female echidna at Wattleridge IPA could cross the burnt area while she continued to forage over the rest of her range. If it survived the larger fire, a female echidna in Warra NP could only forage in burnt country and may have had to alter its behaviour to find ants and termites (Peter Croft, pers. comm.). Echidnas do not generally move beyond their home range (Augee *et al.* 1992) and thus those echidnas whose home range habitat was burnt out would need to adapt to the changed environment.

While the Warra NP fire achieved its objective to reduce the risk of wild fire impacting on life and property (National Parks and Wildlife Service NSW 2015), the Wattleridge IPA fire achieved a broad range of objectives encompassing conservation, cultural revitalisation, and knowledge and capacity development. Our model of co-developed cultural burning and indicator species monitoring can be used directly by the land managers themselves to inform decision making for fire management. Cultural burning provides a mechanism for the Banbai rangers to fulfil their cultural responsibilities to care for their Country and the echidna. For many Indigenous communities, land management is embedded in their culture, and through their maintenance, or in this case revival of cultural actions, they deliver an array of environmental, social, and cultural benefits that build social–ecological resilience (Maclean *et al.* 2013; Walsh *et al.* 2013). For example, in Venezuela, both environmental conservation and Pemon cultural survival depend on the maintenance of traditional Indigenous burning practices (Sletto and Rodriguez 2013). Furthermore, the use of a cultural keystone species is likely to enhance engagement of Indigenous and wider communities, and contribute to broader inclusion and biodiversity conservation outcomes. Garibaldi and Turner (2004) provided examples from North America to show that the use of cultural keystone species

‘contributes to the development of a more holistic perspective of ecosystems and provides us with one more avenue through which to emphasise the importance of species and habitats to particular peoples and to all humanity.’

Wattleridge IPA is Aboriginal-owned and managed, under an Indigenous-driven co-governance engagement (Hill *et al.* 2012) between the Banbai Nation and Australian Government. Non-Indigenous researchers were invited to work with the Banbai rangers using cross-cultural science to monitor the outcomes of burning. In terms of participation in this research, Indigenous rangers chose the indicator species, discussed their experience and learning about cultural burning, recorded Indigenous knowledge related to the echidna, learnt about (through participation) the Western scientific study of fire ecology, collected the data, discussed the research in their communities, co-presented the research at conferences and were co-authors with their non-Indigenous colleagues. The non-Indigenous scientists learnt from Indigenous rangers, reviewed the scientific literature, co-developed the experiment with the rangers, collected, analysed, and disseminated the data. This cross-cultural research will inform adaptive management, but it is also important to note that this was a preliminary study with limitations. More rigorous, long-term cross-cultural research is recommended, and the Banbai rangers have identified other plant and animal species to monitor. Working together, we hope to improve our monitoring methods and continue to produce practical research outcomes. Hill *et al.* (2012) suggested that engagements in which Indigenous groups do not compromise their power are the best option to sustain Indigenous knowledge and reach outcomes that benefit from knowledge integration. Our model of cross-cultural monitoring could be deployed in other contexts, if land owners and decision makers are willing to devolve power and allow trans-disciplinary and cross-cultural research to inform more sustainable and inclusive ways of managing Country.

4.5. Conclusion

Sletto and Rodriguez (2013: 157) described ‘a global effort [that] is now underway to reintroduce Indigenous burning practices as a permanent tool in landscape management’. In south-eastern Australia, the revival of cultural burning is in its infancy compared to that of northern Australia, but it has great potential. Similar to other examples of reinstatement of Indigenous burning practice globally, while the core practice is fire management, the application of cultural burning has far broader implications: allowing Indigenous groups to re-establish access to and connect with Country, rebuild cultural knowledge, and protect animals and ecosystems that are important to them. We have described a process whereby an Indigenous group was able to relearn and reconnect

to an ancient cultural practice in a contemporary environment, which could have applications globally for Indigenous groups who have been dispossessed or disconnected from their land or cultural practices.

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STATEMENT OF AUTHORS' CONTRIBUTION

We, the PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated in the *Statement of Originality*.

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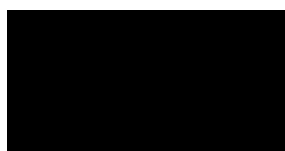
Type of work	Page number/s
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Fig 4.1 ^a	103
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Table 4.1	104
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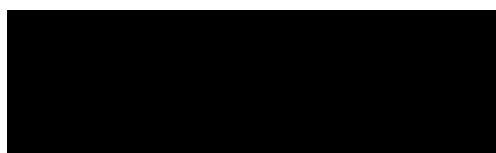
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Chapter 5. Indigenous cultural burning had less impact than wildfire on the threatened Backwater grevillea (*Grevillea scortechinii* subsp. *sarmentosa*) while effectively decreasing fuel loads

Title of Article:

‘Indigenous cultural burning had less impact than wildfire on the threatened Backwater grevillea (*Grevillea scortechinii* subsp. *sarmentosa*) while effectively decreasing fuel loads’

Authors:

Michelle B. McKemey, Banbai Rangers, Maureen (Lesley) Patterson, John T. Hunter, Malcolm Ridges, Emilie J. Ens, Cara Miller, Oliver Costello and Nick C. H. Reid

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5.0. Abstract

Indigenous self-determination, land rights and caring for Country programs are enabling Indigenous peoples across the world to re-establish their customary roles in biodiversity conservation and cultural fire management. In Australia, Indigenous-controlled lands form the majority of the protected area estate, harbour almost 60% of listed threatened species and maintain high levels of biodiversity. This study used cross-cultural (Indigenous and Western) methods to monitor the impact of Indigenous cultural burning versus wildfire on the threatened plant, Backwater grevillea (*Grevillea scortechinii* subsp. *sarmentosa*). Cultural burning resulted in lower mature grevillea mortality and less impact on reproductive output than wildfire. Both fires stimulated a mass germination event but the cultural burn preserved a multi-aged population while the wildfire killed 99.6% of mature shrubs. Comparison of fuel load changes resulting from cultural burning, hazard reduction burning and wildfire indicated that fuel loads were reduced by all fire treatments, although the cultural burn was less severe than other fires. Our case study of the Backwater grevillea and its Banbai custodians provides an example where Indigenous rangers have adopted a plant into their cultural management framework. They are conserving this threatened species using culturally driven, holistic management that is locally focused and supported by cross-cultural knowledge.

Key words: Indigenous knowledge, fire ecology, threatened species, prescribed fire management, cultural fire, cross-cultural knowledge and practice, Aboriginal rangers, southeast Australia

5.1. Introduction

Indigenous peoples have adapted to their environment in ways that conserve both ecosystems and livelihoods in integrated social–ecological systems (Folke 2004). Colding and Folke (1997) shared examples of traditional communities who have co-evolved over long periods with species now identified as ‘threatened’, ‘endemic’ and ‘keystone’, and developed social restraints that resulted in Indigenous-led biological conservation. However, biocultural diversity (interlinked biological and cultural diversity, as per Potts *et al.* 2016; Maffi 2018; Hughes and Vadrot 2019) is threatened by human population growth, increasing consumption and globalisation (Loh and Harmon 2014). Ongoing declines in biocultural diversity have prompted initiatives to increase opportunities for Indigenous people to engage in managing their ‘Country’ (ancestral Indigenous lands) using cultural practice (Leiper *et al.* 2018). Globally, formal recognition of Indigenous peoples in conservation is increasing, leading to multiple benefits to communities and national and international biodiversity goals and obligations (Ens *et al.* 2016; Garnett *et al.* 2018; Fa *et al.* 2020). One example is the revival of Indigenous cultural fire management practices world-wide (Russell-Smith *et al.* 2009; Lake *et al.* 2017; Bilbao *et al.* 2019; Mistry *et al.* 2019; Moura *et al.* 2019; McKemey *et al.* 2020a). Fire is a powerful tool that Indigenous communities use for subsistence purposes as well as a wide variety of social, cultural, spiritual and practical reasons (Boyd 1999; Trauernicht *et al.* 2015; Ens *et al.* 2017; Ansell and Evans 2019).

In Australia, from the 1990s, the establishment of community ranger groups and Indigenous Protected Areas (IPAs) facilitated many Indigenous peoples to re-connect to, and participate in, cultural and natural resource management activities (Altman and Kerins 2012). IPAs are voluntarily protected areas of land and sea managed by Indigenous groups and contribute over one hundred million hectares, or 54%, of Australia’s National Reserve System (Department of Environment and Energy 2019). Leiper *et al.* (2018) found that at least 59.5% of threatened species occur on Indigenous peoples’ lands and several studies have concluded that genuine cross-cultural partnerships are an essential underpinning for collaborative work and conservation outcomes (Ens *et al.* 2015; Renwick *et al.* 2017; Lindenmayer *et al.* 2020). Case studies include the Pintupi people’s partnership with ecologists to manage bilby (ninu or *Macrotis lagotis*) and great desert skink (tjalapa or *Liopholis kintorei*) at Kiwirrkurra IPA (Crossing and Thomas 2015); the Nawarddeken’s care of the rainforest tree Anbinik (*Allosyncarpia ternata*) (Warddeken Land Management Limited 2018; Ansell and Evans 2019); and the Bundjalung people’s conservation of the Byron Bay orchid (*Diuris byronesis*) at jointly-managed Arakwal National Park (CSIRO *et al.* 2019). Ridges *et al.* (2020) and Hooper (2019) discussed Aboriginal core values in relation to the

conservation of the threatened malleefowl (yungadhu, *Leipoa ocellata*) and Australian brush turkey (*Alectura lathami*), respectively. Garnett and Woinarski (2007) linked the decline of many species in recent decades to the cessation of traditional Indigenous stewardship and concluded that Indigenous management of fire and other threats at a landscape scale benefits a number of threatened species.

In southeast Australia, a revival of Aboriginal cultural burning is occurring. ‘Cultural burning’, defined as ‘burning practices developed by Aboriginal people to enhance the health of the land and its people’ (Firesticks Alliance Indigenous Corporation 2019), is used to describe the application of fire, while ‘cultural fire management’ encompasses broader cultural practices, values, heritage and land management activities (Office of Environment and Heritage 2016; McKemey *et al.* 2020b). An emerging field of academic research aims to monitor and evaluate the outcomes of Indigenous cultural burning activities (Maclean *et al.* 2018). Concurrently, Indigenous cultural fire managers are seeking support to produce ethical research that translates and communicates the holistic benefits of cultural fire management (Firesticks Alliance 2020). The majority of studies to date have taken a qualitative approach. For example, several papers have claimed that cultural burning protects threatened species and reduces wildfire risk (Maclean *et al.* 2018; Robertson 2019) but there is limited empirical evidence to support these claims in southeast Australia (McKemey *et al.* 2020b). Research into cultural fire management provides an opportunity to explore cross-cultural (or two-way) techniques, which are described as ‘using combinations of Indigenous and non-Indigenous knowledge and methods and with the involvement of both Indigenous and non-Indigenous people towards a common goal’ (Ens 2012: 46; for examples, see Hill 2003; Ens *et al.* 2012; Hoffmann *et al.* 2012; Walsh *et al.* 2013).

On the New England Tablelands of New South Wales (NSW), the Indigenous Banbai rangers manage the 480 ha Wattleridge IPA (Fig. 5.1) for the conservation of biodiversity and cultural heritage (Patterson and Hunt 2012). Sixteen species of threatened fauna and flora have been recorded in the dry sclerophyll forest communities of Wattleridge IPA (Hunter 2003b; Milledge 2016). Despite disruptions to their traditional cultural practices (Sonter 2018), the Banbai rangers started to renew their cultural burning practices from 2014. The Banbai rangers initiated a cross-cultural monitoring program alongside Western scientists (McKemey *et al.* 2019b) to monitor the impact of cultural burning on Backwater grevillea (*Grevillea scortechinii* subsp. *sarmentosa*, also known as Black or Toothbrush grevillea). The Backwater grevillea is a low spreading shrub which occurs in dry sclerophyll forest, restricted to granite country on the New England Tablelands (Threatened Species Scientific Committee 2013). The subspecies is listed as Vulnerable in NSW

under the *Biodiversity Conservation Act 2016* (BC Act) (Department of Planning Industry and Environment 2020a). It was previously listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) but was de-listed in 2013 due to localised high abundance (Department of the Environment 2020) with up to 20,000 individuals found in Wattleridge IPA and the surrounding Backwater area (Hunter 2003b). Threats include cattle grazing, vegetation clearing, roadworks, inappropriate fire regimes, weed invasion and feral animals, and the grevillea's restricted distribution increases its vulnerability to local extinction (Minister for the Environment 2008). The need for further work in the cultural fire management and cross-cultural monitoring space is increasing due to the increasing frequency and intensity of wildfire under climate change (Bureau of Meteorology and CSIRO 2020; Mullins *et al.* 2020). An example of this was the 2019 Crown Mountain wildfire during Australia's catastrophic 2019/20 wildfire season, which burnt 9091-ha in the region encompassing the range of the Backwater grevillea (Filkov *et al.* 2020).

The fire response syndrome of a plant species, based on its vital attributes and fire response traits, has profound effects on post-fire population dynamics and community composition (Noble and Slatyer 1980; Gill and Bradstock 1992; Clarke *et al.* 2009). Some shrubs are killed by fire and, following fire, depend on seed germination and a sufficient inter-fire period to survive and reproduce (obligate seeders), whilst others resprout following fire (Croft *et al.* 2006). The maturation time has been given the term 'primary juvenile period' (PJP), which refers to the time taken for seedlings to flower and produce viable seed. 'Secondary juvenile period' (SJP) is the time to flowering after resprouting (Gill and Bradstock 1992; Clarke *et al.* 2009). Maturation times of new recruits for plants killed by fire is a critical biological variable in the context of fire regimes because this time sets the lower limit for fire intervals that can cause local population decline or extirpation (Keith 1996; Clarke *et al.* 2009). As such, 'High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition' has been listed as a Key Threatening Process under the BC Act (Department of Planning Industry and Environment 2020c). On the New England Tablelands, Kitchin (2001) found that dry sclerophyll forest communities subjected to frequent fire displayed reduced shrub species abundance (including the seed bank), richness and simplified structure. Various fire response traits have been suggested for the Backwater grevillea, including: resprouting from basal buds (Clarke *et al.* 2009); killed, soil stored seed bank (Clarke unpublished); and 'occasionally resprouting but largely an obligate seeder with a high germination rate' (Hunter 2003b). Populations at Warra National Park (NP) and Wattleridge IPA were noted to germinate *en masse* after fire (Hunter 2005).

The PJP is not known (Clarke *et al.* 2009) and SJP was observed to be 3 years (Hunter 2003b). Fire management recommendations for the Backwater grevillea were ‘no fire more than once every 11 years’ (Hotspots Fire Project 2016).

The Conservation Advice for the Backwater grevillea identified research priorities, including assessments of: the species’ response to fire; more precise total population size, distribution, ecological requirements; and the relative impacts of threatening processes (Minister for the Environment 2008). Coupled with the need for quantitative research related to contemporary cultural burning, cross-cultural monitoring of the Backwater grevillea provided an opportunity to address these key research gaps. The aims of this study were to: (1) undertake cross-cultural monitoring of the Backwater grevillea, through interviews and on-ground monitoring with Banbai rangers, and Western science techniques of experimental design, analysis and scientific writing; (2) compare the fire effects of Aboriginal cultural burning, NPWS hazard reduction burning and the 2019 Crown Mountain wildfire; (3) investigate changes in mortality, recruitment, reproduction and fire response traits of the Backwater grevillea following cultural burning and a wildfire, and (4) use this information to make recommendations for effective fire management and conservation of the Backwater grevillea based on the Banbai rangers’ Indigenous knowledge and Western science, and discuss the role of Indigenous landholders and rangers in threatened species conservation.

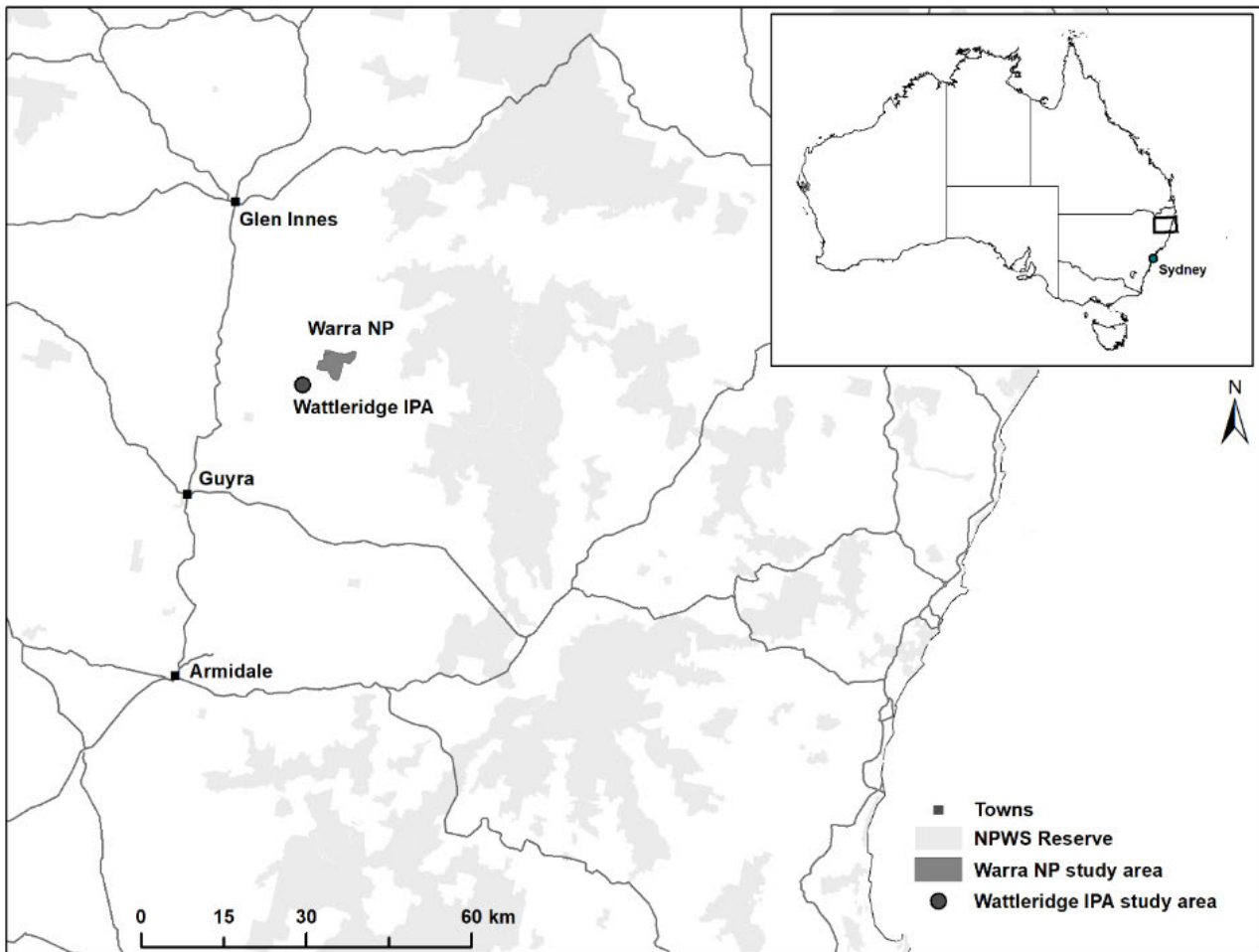


Figure 5-1 Location of the study area (Wattleridge Indigenous Protected Area) and adjoining Warra National Park (NP) in northern New South Wales, Australia.

5.2. Methods

The cross-cultural monitoring of the Backwater grevillea employed socio-cultural and ecological monitoring techniques. Throughout the study period (2014–2020), the Banbai rangers, Indigenous fire practitioners and non-Indigenous scientists collaborated to co-develop the research project, collect data, share observations, discuss the findings of the research, develop the manuscript for publication and share the findings with a broader audience.

5.2.1. Socio-cultural research

An inductive approach to qualitative socio-cultural research was adopted, using participatory action research and semi-structured interviews (Babbie 2013). For the participatory action research, a non-Indigenous scientist (MM) and the Banbai Indigenous rangers participated in two activities (Fig. 5.2): implementing a cultural burn, and monitoring the Backwater grevillea population before and

after the burn. Semi-structured interviews were undertaken during the cultural burn and grevillea monitoring over a period of five years. Interviews were recorded audio-visually, transcribed, and later coded and qualitatively analysed around the themes (Schwandt 2014) of cultural burning, significance of the Backwater grevillea, impact of fire on Backwater grevillea, threats and management related to Backwater grevillea, and collaborative monitoring (Appendix 5.1). Eight Banbai rangers with varying levels of experience participated (Table 5.1). Five Banbai rangers were interviewed prior to the cultural burn in 2015, four during the burn and seven after the burn. Three Banbai rangers were interviewed following the Crown Mountain wildfire in 2020. Eight Banbai rangers (including two Elders who were also rangers) participated in data collection and monitoring Backwater grevillea. The participation of rangers depended on their availability and willingness to be interviewed.

Table 5-1 Banbai participants in interviews and grevillea monitoring.

Initials	Gender	Role	Ranger Experience	Interview year
LP	Female	Elder & Ranger	12 years	2015, 16, 17, 18, 20
MT	Male	Elder & Ranger	10 years	2015, 16, 18, 20
CP	Male	Ranger Supervisor	11 years	2015, 16, 17
TP	Male	Ranger Supervisor	11 years	2015, 16, 17, 18, 20
DC	Male	Ranger	10 years	2016, 18
KP	Male	Ranger	9 years	2015, 16, 17, 18
JJ	Male	Ranger	4 years	2018
PA	Male	Ranger	4 years	Not interviewed, participated in monitoring

5.2.2. Collaborative ecological monitoring

A collaborative ecological monitoring program was undertaken to assess fuel loads, fire effects and grevillea population dynamics. Nomenclature follows that of the PlantNET Information System (National Herbarium of NSW 2020). Pre and post-burn assessments based on a Before–After–Control–Impact (BACI) experimental design were undertaken (Underwood 1991). In 2015, 30 monitoring plots (15 each of control and impact plots) were established across the two study sites (12 at Wattleridge IPA, 18 at Warra NP). Control and impact plots had similar vegetation type, soil, geology, climate, slope, aspect and location (Hunter 2005). Plots were randomly placed in each

zone. Plot dimensions were 20 × 20 m (400 m² ‘large plots’) (akin to Department of Environment Climate Change and Water 2011) and each plot included four nested transects of 5 m² (totalling 20 m² of ‘transects’ per plot) and five quadrats of 1 m² (‘small plots’).

A cultural burn was undertaken at the Wattleridge IPA on 16 August 2015 by the Banbai rangers (with the Rural Fire Service NSW present). This fire was a small (4 ha), low-severity, mosaic burn in dry sclerophyll forest. Time since last fire was approximately 30 years (Rural Fire Service NSW 2015). A hazard reduction burn was also undertaken in 2015. This fire was a large (685 ha) moderate-intensity burn on 20 October by NPWS and RFS at Warra NP and adjoining private land. The planned burn area was 351 ha; however, another fire started nearby and met with the planned burn to increase the total burnt area to 685 ha. Time since the last fire was 16 years (National Parks and Wildlife Service NSW 2015). For both planned burns in 2015, only the impact plots were burnt, control plots remained unburnt. In December 2019, the very large (9091 ha) Crown Mountain wildfire burnt all of the control and impact BACI plots at Wattleridge IPA and Warra NP. Time since the last fire was four years.

We measured indicators of fire effects (impact on variables before and after fire) across 30 large plots before and after (6 weeks, 1 year, 3 years) cultural (Wattleridge IPA) and hazard reduction (Warra NP) burning, and after (0.5 year) wildfire at both locations. Overall fire severity (broadly defined as ecosystem impact of fire; Keeley 2009) was determined based on: mean fuel load decrease (t/ha) (measured using overall fuel hazard assessment, as per Hines *et al.* 2010), mean tree scar height (m) (mean height of scorch on tree bole bark, visually estimated in large plots), mean percentage of plot burnt (per cent bare ground after fire in all small plots), fire plan optimum intensity (intended fire intensity, recorded in prescribed fire plans, as per National Parks and Wildlife Service NSW 2015; Rural Fire Service NSW 2015; Department of Planning 2020), total fire size (ha) and estimated canopy scorch (%) (recorded in prescribed fire debrief reports and Google Earth Engine Burnt Area Map, Department of Planning Industry and Environment 2020b).

At Wattleridge IPA, each large plot was measured four times: before (2015) and after (2016, 2018) cultural burning, and after wildfire (2020). We measured the total number (count) and size (height and width of plant) of mature (>20 cm height) Backwater grevillea. For each plant, the following details were noted: burnt/unburnt, alive/dead, reproductive stage (none/ flower/ fruit), fire response (resprouting/seeding). In all transects, all grevillea individuals (seedlings and mature plants) were counted and measured. A representative sample of grevillea seedlings were dug up and assessed to determine if they were individual plants or suckers from a larger plant.

Seven response variables (count of seedlings and mature grevilleas, reproduction, fuel load, fuel load decrease, tree scar height and percentage plot burnt) were analysed in relation to time (2015, 2016, 2018, 2020) and fire treatment (control vs impact) with R statistical software (R Core Team 2014). For exploration of counts of both seedlings and mature grevilleas, we used mixed models with treatment (i.e. control and impact), year and the interaction of these two factors as fixed effects, and individual plot as a random effect. A Fisher's Exact Test was used to test for differences in reproduction affected by treatment and year. A two-way ANOVA model was used for the fuel load data and a one-way ANOVA to assess change in fuel load. For both of these fuel load analyses ANOVA model assumptions of normality of residuals and heterogeneity of variances were satisfied. Due to differences in group variance values a Welch's ANOVA was used to assess tree scar height. Categories of percentage of plot burnt were analysed using a Chi-square test of independence.



Image 5-1 Cross-cultural monitoring of Backwater grevillea (clockwise from top left): (a) measuring a large, old shrub prior to fire in 2015; (b) cultural burning of the treatment plots in 2015; (c) mass recruitment of juvenile shrubs, and (d) monitoring following the Crown Mountain wildfire in 2020.

5.3. Results

5.3.1. Socio-cultural research

Before they began work at the Wattleridge IPA, many of the Banbai rangers were not familiar with the Backwater grevillea or its traditional values. In 2015, prior to cultural burning, the rangers indicated that the grevillea had become important to them, as it was a declared threatened species that was only found in the Wattleridge IPA region. They felt a responsibility to look after this plant. They were interested to learn if cultural burning would benefit the grevillea. One ranger predicted that *‘Having a winba [Banbai word for fire] will push the seed out and create more of it’* (TP). The rangers said that mitigation of wildfire risk was one purpose of cultural burning: *‘The difference to the way we burn is ... we set it up so it’s not just gonna fly for the bush. And so we just slowly move through the bush and don’t ... burn everything ... A wildfire would just kill everything and start crown fires, so we just try to keep it low’* (KP).

In 2016, the year following the cultural burn, the Banbai rangers noted that a lot of Backwater grevillea came up after the cultural burn. They stated that the cultural burn *‘went well’* and benefited the grevillea by stimulating establishment of new plants. Some of the rangers said that leaf litter was inhibiting grevillea growth and the fire reduced the ground cover to allow it to establish. Ranger and Elder LP expressed that *‘We know now that it comes back really strong after a good winba’* and *‘the grevillea down here has come back ten-fold. We’ve proven that every fire we do, that grevillea will regenerate after a winba’*.

In 2017, the Banbai rangers continued to say that cultural burning is a good tool for the management of Backwater grevillea. In 2018, three years after the cultural burn, LP said that the grevillea recruitment was so dense *‘it came back like a carpet’*. While the cultural burn killed some of the large, old shrubs, fire had awakened the seeds, and the new plants were mostly seedlings, not suckers. Old shrubs in the unburnt control plots and those left unburnt by the patchy cultural burn were reproducing: *‘The unburnt areas had a lot of bigger ones through them so they were starting to flower a lot more’* (DC). They felt that the population was healthy because *‘they reproduce flowers and seeds every year. Some of them might need a bit of winba to reinvigorate them but it is a very healthy population here’* (LP).

The rangers listed threats to the Backwater grevillea as intense fire, kangaroos, feral animals, pigs, drought and humans. They described their preferred management actions for the grevillea as: cultural burning to reduce wildfire risk; feral animal management; and educating people, to look

but not touch. LP described the variable outcomes of burning on the grevillea, which are dependent on *‘where you’ve got them in the landscape and what sort of winba you are using’*. From their observations, the rangers agreed that patchy, low severity burning was best, and it worked well at Wattleridge IPA. Cultural burning leads to *‘healthy Country and healthy people’* (LP & TP). The rangers wanted to continue the monitoring. *‘I can say it has worked really well, the winba with the grevillea, it has come a long way and to keep doing it would be great’* (TP).

In 2020, following the Crown Mountain wildfire, the Banbai rangers observed that the larger Backwater grevillea plants died and young plants were emerging. The rangers noted that many Australian native plants need fire, but cool burns were preferable to hot burns. They were concerned that the wildfire had *‘burnt everything right out’* and several months later *‘there is still nothing coming back’* (MT) where the fire was very hot. TP noted that cultural burning had slowed down two wildfires that came into Wattleridge IPA in 2019, but the combination of drought and severe fire meant that the Crown Mountain wildfire *‘hit us pretty hard’*. LP spoke about the frequency of fire: *‘Native [plants] love winba but not on a regular basis. You have got to give the time for everything to settle, move onto the next burn patch, then come back in another two or three years. Don’t let your Country get sick again, but not burning too frequently. If you burn too much you will make it sick too, killing all the nutrients.’* The rangers intend to continue their cultural burning program, noting *‘Us Banbai rangers have got the knowledge and the know-how to do it on our own property. Cultural burning is the way to go, you know your canopy and the old trees are going to survive if you do low-intensity [low severity] burns. It does the Country better, it doesn’t take as long to come back, as it would with a wildfire’* (LP).

5.3.2. Collaborative ecological monitoring

The cultural burn undertaken by the Banbai rangers in 2015 was smaller, patchier and less intense than the hazard reduction burn undertaken by NPWS on neighbouring Warra NP in 2015 (Table 5.2). The cultural burn had negligible impact on the canopy, while the hazard reduction burn scorched 10% of the canopy. The overall fire severity of the cultural burn was low, while the hazard reduction burn was moderate. In comparison to the 2015 fires, the effect of the Crown Mountain wildfire was very severe. The wildfire was large and impacted 90% of the canopy. The tree fire scars were higher and the fire effects were more uniform (98% burn coverage across all plots). In general, the three fires resulted in a similar decrease in fuel load (mean 10 t/ha) and the change in fuel load was significantly affected by time and treatment ($p < 0.001$; Fig. 5.2).

Table 5-2 Fire effects (mean $\pm$ SE, sample size in parentheses) and overall fire severity in impacted plots after the Wattleridge IPA cultural burn (2015), Warra NP hazard reduction burn (2015) and Crown Mountain wildfire (2019). The mean fuel load decrease did not differ significantly between the three types of fire. For tree scar height and proportion of the plot burnt, means followed by a different superscript differed significantly at $p < 0.05$.

Indicator	Wattleridge IPA cultural burn 2015	Warra NP hazard reduction 2015	Crown Mountain wildfire 2019
Mean fuel load decrease (t/ha)	8.9 ± 1.59 (6) ^a	7.8 ± 1.49 (9) ^a	10.8 ± 0.81 (30) ^a
Mean tree scar height (m)	3.8 ± 0.65 (6) ^a	5.8 ± 1.25 (9) ^a	12.2 ± 1.18 (30) ^b
Mean percentage plot burnt (%)	59 ± 8.0 (6) ^a	81 ± 5.1 (9) ^b	98 ± 1.18 (30) ^c
Total fire size (ha)	4	685	9091
Fire plan optimum intensity	Low*	Moderate-high*	Unplanned
Estimated crown scorch	0%	10%	90%
Overall fire severity	Low	Moderate	Very Severe

*Fire plan optimum intensity uses the definitions in Rural and Land Management Group (2012: 17, 20) *Australasian Fire Authorities Council Bushfire Glossary* of low intensity fire as 'a fire which travels slowly and only burns lower storey vegetation, like grass and lower tree branches, with an average intensity of less than 500 kW.m⁻¹ and flame height less than 1.5 m. Usually causes little or no crown scorch and is easily controlled' and high intensity fire as 'fires with an average intensity greater than 3000 kW.m⁻¹ and flame heights greater than 3 m, causing complete crown scorch or possibly crown fires in forests'.

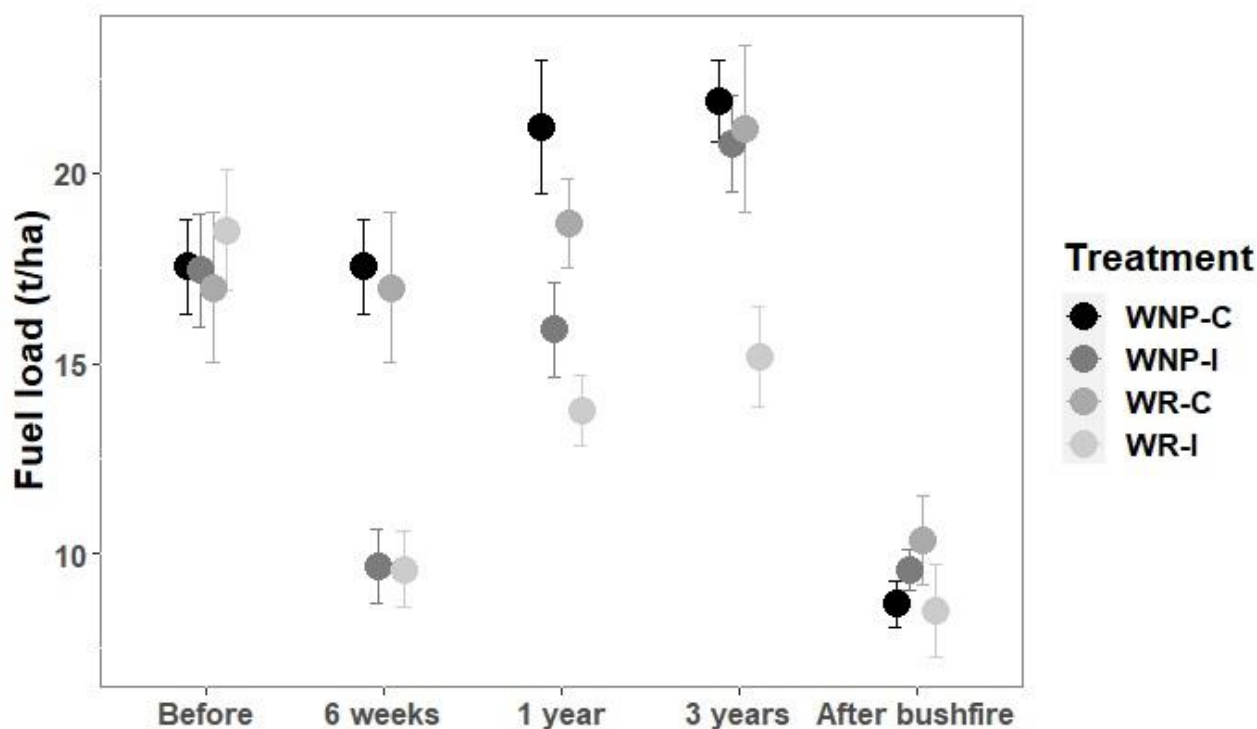


Figure 5-2 Fuel load (t/ha) before and after (6 weeks, 1 year, 3 years) cultural and hazard reduction burning, and after wildfire in Wattleridge IPA (WR) and Warra NP (WNP) control (WNP-C and WR-C) and impact (WNP-I and WR-I) plots. Error bars indicate 95% confidence intervals.

In 2016, 43% of the mature shrubs that were alive in pre-burn monitoring had died in the plots that were impacted by cultural burning (Fig. 5.3). Three years after cultural burning (2018), the count of mature shrubs had increased fivefold in the impact plots. The control plots showed negligible change. All plots were burnt by the Crown Mountain wildfire, after which (2020) mortality of mature shrubs was 99.6%: the total number of mature shrubs across all 400 m² plots was 277 in 2018, falling to 1 in 2020 after the wildfire. Mature shrub count was significantly affected by year, after wildfire ($p < 0.001$).

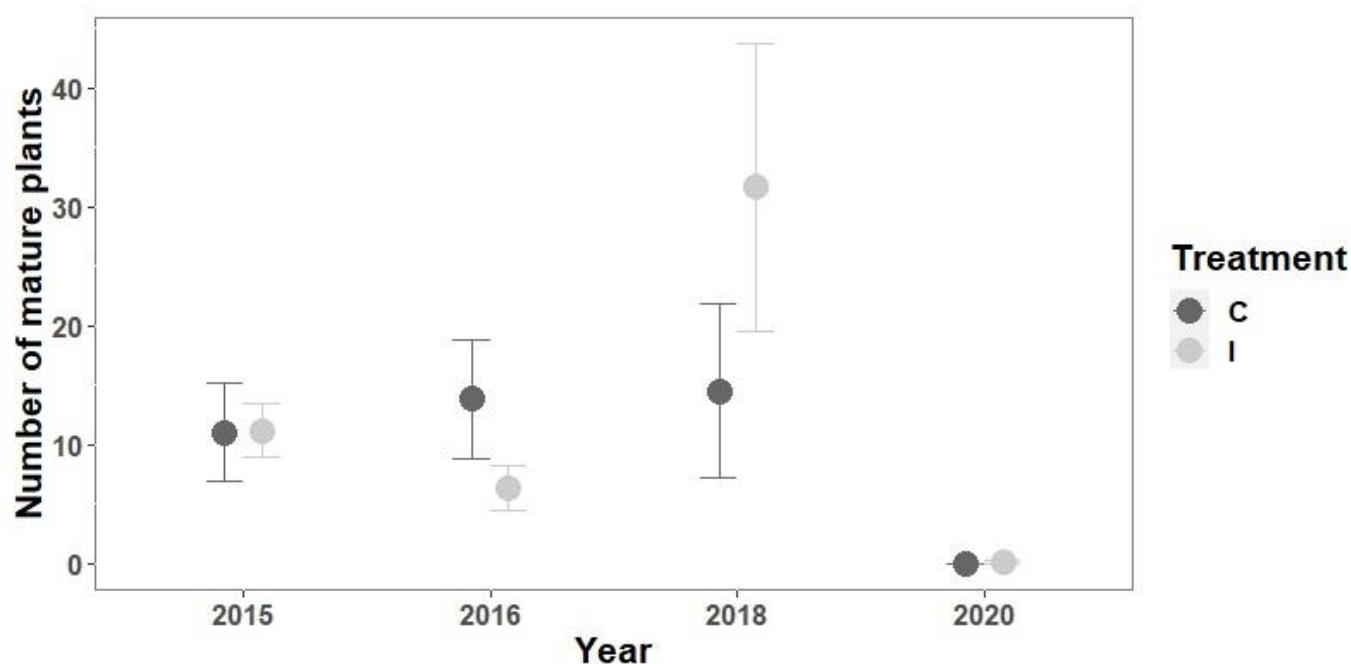


Figure 5-3 Mean count of mature *Backwater grevillea* before (2015) and after (2016, 2018) cultural burning, and after wildfire (2020) in Wattleridge IPA control (C) and impact (I) plots. Error bars indicate 95% confidence intervals.

One year after cultural burning, grevillea seedlings increased from a mean count of 1.7 to 79.0 per 20 m² transect, but there was little germination in unburnt transects (Fig. 5.4; treatment x year interaction, $p = 0.017$). Three years after cultural burning, the mean count of grevillea seedlings had decreased to 29.8 per 20 m² in the impact transects, which was still an 18-fold increase from the pre-fire population. The control transects had negligible change with an average of 1.2 plants per 20 m². After all plots were impacted by the wildfire (2020), the mean count of seedlings in control transects increased to 210.0 per 20 m² in the control transects, and to 100.8 in impact transects (year, $p < 0.01$).

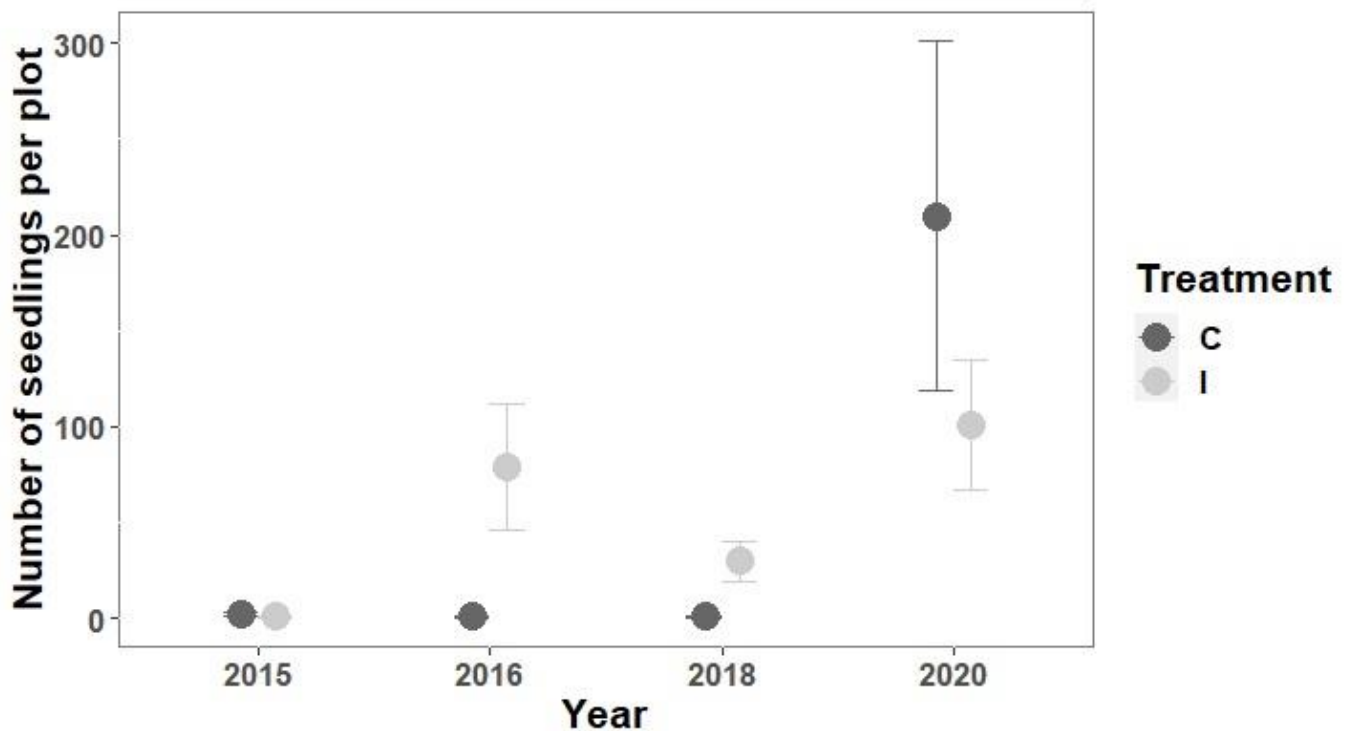


Figure 5-4 Mean count of Backwater grevillea seedlings before (2015) and after (2016, 2018) cultural burning, and after wildfire (2020) in Watteridge IPA control (C) and impact (I) transects. Error bars indicate 95% confidence intervals.

Prior to cultural burning, there were similar numbers of mature reproductive grevillea in the pre-burn impact (17 of 67 plants bore flowers or fruit, or 25% of the total number of mature plants) and control plots (18 of 66 plants bore flowers or fruit, or 27% of the total number of mature plants) (Fisher's Exact Test, $p = 0.85$). In the year after the cultural burn (2016), there was a significantly lower percentage of grevillea with flowers or fruit in the impact plots (3% of 38 mature plants) compared to the control plots (59% of 83 mature plants) ($p < 0.001$). Three years after cultural burning (2018), there was still a significantly lower percentage of mature shrubs reproducing in impact plots (27% of 190 plants) than in control plots (90% of 87 plants) ($p < 0.001$). After all plots were burnt in the wildfire, only one mature shrub remained in 2020 in any plot and it was re-sprouting and not reproductive. Across all transects in all plots in 2020, there were 1,865 new seedlings (these were not suckers).

5.4. Discussion

In this study, we compared the fire effects of Indigenous cultural burning to a nearby hazard reduction burn, followed by an unforeseen wildfire. Results showed that the cultural burn was smaller, patchier (a mosaic of burnt and unburnt patches), less intense and less severe than the hazard reduction burn and wildfire. All fires resulted in a similar decrease in fuel load. We found

that the cultural burn had a lower impact on mature Backwater grevillea survival compared to wildfire. The cultural burn created a multi-age population, with mature shrubs contributing to the seed bank and seedlings providing the next generation of grevilleas. While mass recruitment was observed following the fires, the high fire frequency (two fires in four years) is likely to have affected the seed bank. The cultural burn germinated many seeds, depleting the number available for germination after the subsequent wildfire, resulting in half as much recruitment in impact plots as control plots following the wildfire.

This study addressed several previous Backwater grevillea knowledge gaps. We found that obligate seeding was a far more prevalent fire response than resprouting. The wildfire stimulated more seedling recruitment in previously unburnt plots than the cultural burn, which may be due to heat penetrating deeper into the soil profile during the wildfire (Tangney *et al.* 2020). We also found that three years after the cultural burn, some of the grevilleas in the impact plots were able to complete their secondary or primary juvenile period, while others were not yet reproductive. However, the percentage of grevilleas reproducing was still minimal compared to the 90% in the control plots and we predict it will take longer for seedling maturation and to achieve a similar ‘normal output’ of seed rain after cultural burning. Recovery of the seed bank may have been depressed for longer than 3 years. We suggest that at least 50% of the grevillea population should be reproductive before the population is considered to have completed the secondary or primary juvenile period. Future research could include measuring the seed bank before and after fire, tagging plants to closely monitor fire response, maturation (PJP and SJP) periods and reproductive capacity (e.g. output of young plants cf. old-growth shrubs), as well as mapping and monitoring of grevillea populations in Warra NP, Mann River Nature Reserve and on private land. The findings of this study have parallels in other international contexts, such as in the US, where rare, fire-dependent plants such as the Tecate cypress (*Hesperocyparis forbesii*) are vulnerable due to immaturity risk and fire–climate interactions that may impact their persistence in a future of climate change and altered fire regimes (Brennan and Keeley 2019).

The Backwater grevillea has a restricted distribution which makes it vulnerable to one-off catastrophic events, although it was recently de-listed as a threatened species under the EPBC Act 1999. The Crown Mountain, Pinkett, Kangawalla and other wildfires (part of the ‘Black Summer Fires’ of 2019–20) that burnt almost 19 million ha of southeast Australia (Filkov *et al.* 2020), had a catastrophic impact across the majority of the grevillea’s range. Future cultural burning regimes implemented by the Banbai rangers will need to be carefully timed to avoid depleting the seed bank of the grevillea while also balancing the mitigation of wildfire risk. The data collected through this

study will guide the Banbai rangers in their adaptive management of Wattleridge IPA and should inform threatened species and protected area management plans. We recommend: identifying and protecting Backwater grevillea populations as a high priority; continued cross-cultural monitoring to inform adaptive management; a re-assessment of the conservation status of the Backwater grevillea; taking a more precautionary approach to the conservation of restricted and rare species; and consideration of compounding impacts such as climate change, drought and fire, as per the *Blueprint for a conservation response to large-scale ecological disaster* in Dickman *et al.* (2020).

The Banbai rangers concluded that cultural burning was the best fire management for conservation of the Backwater grevillea as the low severity burning stimulated establishment of new seedlings but did not kill all of the mature shrubs. Following the cultural burn, the Banbai rangers said that the grevillea population was healthy because ‘they reproduce flowers and seeds every year’. They noted that cultural burning slowed down the wildfire, but due to drought and extreme fire conditions, Wattleridge IPA was still impacted. The Banbai rangers compared the low-intensity, patchy nature of cultural burning to the severe, destructive nature of wildfire. While these are early findings and continued evaluation may lead to different understanding, our initial collaborative ecological monitoring results concurred with the Banbai rangers’ observations. As research in northern Australia has shown (Ansell and Evans 2019), the Banbai cultural burn resulted in a decrease in fuel load, but was less severe than the hazard reduction burn and wildfire.

Prior to the extreme wildfire weather of 2019–20, the Banbai rangers were only able to implement a few cultural burns on Wattleridge, which although beneficial, were inadequate to provide landscape-scale wildfire risk mitigation. In future, an expanded cross-tenure cultural burning program could evaluate whether cultural burning reduces wildfire risk. Brazil’s Integrated Fire Management program commenced in protected areas and Indigenous territories in 2014, and has already changed fire regimes in some areas, reducing wildfires and helping to protect fire-sensitive vegetation (Schmidt and Eloy 2020).

This study provided an opportunity to share the journey of the Banbai rangers as they care for their Country and the Backwater grevillea. Prior to the project, the Banbai rangers considered that they had limited knowledge regarding the grevillea and they were not aware of any traditional uses or cultural significance of this plant. Their interest in the grevillea emerged because it was brought to their attention as a threatened species. When the Banbai rangers applied a cultural burn, they observed that it had some benefit for the grevillea, which they confirmed through cross-cultural monitoring. Through their monitoring of the grevillea, the Banbai rangers have become more

confident with the application of cultural burning and concluded that cultural burning is the best fire management approach at Wattleridge IPA. It is sometimes assumed that Indigenous conservation requires application of traditional practices (Berkes *et al.* 1994; Colding and Folke 1997) or extensive biocultural, traditional ecological or Indigenous ecological knowledge, discussed in Thomassin *et al.* (2019). However, this assumption overlooks the revitalisation and/or evolution of cultural knowledge and how this contributes to cultural renewal (Bessarab and Ng'andu 2010). While interest in the grevillea may have been triggered by its scientific listing as Vulnerable, and the project progressed within a Western positivist-science framework, the decision to assume stewardship of the grevillea and apply a low-intensity fire regime was a *cultural* decision made by the Banbai based on burning having traditionally been part of a cultural approach to land management (even if it is not known how that was implemented). Through that process, and through participating in a Western science monitoring approach, as a community, the Banbai have reconnected with the grevillea. They are now: observing and understanding the grevillea's life-cycle (i.e. they are understanding its kinship); interacting with its needs and applying cultural burning (i.e. as part of their responsibilities for Country); and making decisions about the rule sets they will apply in future management (i.e. they are re-learning and applying Backwater grevillea Lore). As the Banbai learn more about the grevillea, echidna (McKemey *et al.* 2019b), and all other biophysical and cultural aspects of managing their Country, they are re-awakening the Dreaming in that landscape. This project therefore documents an important part of cultural burning, which is cultural renewal. While this process may have been triggered and motivated by science, it nonetheless will be continued through a cultural paradigm that is motivated by the connection of Banbai with Country and the grevillea. This is a culturally driven approach (Hooper 2019; Ridges *et al.* 2020) to managing threatened species that benefits from management that is local and affords attention to detail, and is based on a deep spiritual connection (similar to the basis of Indigenous fire management described in McKemey *et al.* 2020a; also see Mistry and Berardi 2016). This contrasts with the government-managed Warra NP, which is managed according to fire regimes determined centrally rather than locally, and managed by agency officers who are spread thinly, often under-resourced, time-poor and present on-site for only short periods as they work across the region-wide public park and reserve estate.

The relationship between biodiversity conservation and Indigenous land management is nuanced and complex (Garnett and Woinarski 2007; Nursey-Bray 2009; Leiper *et al.* 2018). Garnett and Woinarski (2007) explained that biodiversity in Australian law is a modern concept, and threatened species conservation may be a collateral benefit of Indigenous landscape-scale land management.

Some threatened species may appear to be insignificant to Indigenous people, due to their rarity, lack of practical function or lack of spiritual significance in Indigenous culture. However, as noted here and by Garnett and Woinarski (2007), culture is ever-changing and it is conceivable that some threatened species have become important parts of Indigenous land management and cosmology. Our case study of the Backwater grevillea and its Banbai custodians provides an example where the Aboriginal community has adopted and integrated a plant into their cultural framework, and by employing cross-cultural methods, are conserving a threatened species using culturally-driven, holistic management, characterised by its local focus and attention to detail.

5.5. Conclusion

Through the use of a cross-cultural monitoring model, we accessed a dual (Indigenous and Western) toolbox (Hill 2003) to provide insight into the conservation of a threatened species. Comparison of fuel load changes resulting from cultural burning, hazard reduction burning and wildfire indicated that fuel loads were reduced by all fire treatments, although effects of the cultural burn were less severe than other fires. Cultural burning resulted in lower mature grevillea mortality and lesser impact on reproductive output than wildfire. Both fires stimulated a mass germination event but the cultural burn preserved a multi-aged population while the wildfire killed 99.6% of mature shrubs. Our study concluded that cultural burning was the best fire management for conservation of the Backwater grevillea, ongoing cross-cultural monitoring is required to inform adaptive management and, in the aftermath of severe wildfire, management to protect Backwater grevillea populations is a high priority, as is a re-evaluation of the conservation status of the Backwater grevillea. The Banbai custodians play an important, ongoing role in the protection of this threatened species. Indigenous caring for Country projects are generally under-resourced (Hill and Williams 2009; Strelein *et al.* 2020) and their outcomes ill-acknowledged (United Nations 2019a; McKemey *et al.* 2020b). Yet, considering that Indigenous peoples manage 40% of the world's ecologically intact landscapes (Garnett *et al.* 2018), effective monitoring and adaptive management is critical to the ongoing survival of biological and cultural diversity.

Higher Degree Research Thesis by Publication

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STATEMENT OF AUTHORS' CONTRIBUTION

We, the PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated in the *Statement of Originality*.

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We, the PhD candidate and the candidate's Principal Supervisor, certify that the following text, figures and diagrams are the candidate's original work.

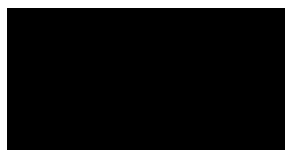
Type of work	Page number/s
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Image 5.1	130

^a Assistance in the preparation of Fig 5.1 was provided by Catherine MacGregor

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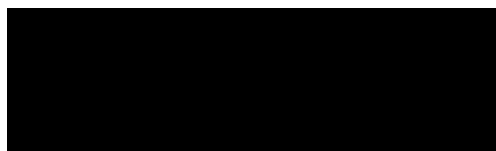
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Chapter 7. Impacts of Indigenous cultural burning versus hazard reduction on dry sclerophyll forest composition, abundance and species richness in southeast Australia

Title of Article:

‘Impacts of Indigenous cultural burning versus hazard reduction on dry sclerophyll forest composition, abundance and species richness in southeast Australia’

Manuscript yet to be submitted to a scientific journal.

7.0. Abstract

Fire has had a profound impact on Australia's landscapes and biodiversity since the late Tertiary. Indigenous (Aboriginal) people have lived in Australia for at least 65,000 years and fire is an integral part of their culture and cosmology. In 2015, an Indigenous cultural burn was undertaken by Banbai rangers at Wattleridge Indigenous Protected Area, New England Tablelands, NSW. We compared the impact of this burn on the composition, cover, abundance and species richness of dry sclerophyll vegetation and fuel hazard, with a hazard reduction burn at nearby Warra National Park, using a Before–After–Control–Impact experimental design. Our study found that the low severity cultural burn and moderate severity hazard reduction burn reduced fuel loads but did not have a significant impact on full floristics or herbaceous vegetation. Only the hazard reduction burn had a significant impact on shrub and juvenile tree (woody species) cover and composition. The abundance of woody species was significantly affected by both types of fire, particularly after the cultural burn, with a mass germination of 'seeder' species. The long unburnt fire regime at Wattleridge IPA may have made vegetation communities more responsive to fire than the more frequently burnt vegetation at Warra National Park, so that the patchy cultural burn had a greater impact on woody species abundance. In terms of ecological and wildfire management outcomes, this study provides evidence to support claims that Indigenous cultural burning decreases fuel loads, stimulates regeneration of shrubs and trees, and manages ecosystems at a local, place-based scale.

7.1. Introduction

Fire has been a major force shaping the distribution and structure of Australian vegetation since the late Tertiary (Bowman 2003a). Ecosystems respond to, and recover from, fire in various ways, depending on factors such as climate, soil, topography, fire regime, management and fire–vegetation dynamics (Miller and Murphy 2017). The frequency of fires, as well as their intensity, type, season of occurrence and extent, are collectively known as the ‘fire regime’ (Gill 1975), and these have a substantial effect on ecosystems and biodiversity (Bradstock *et al.* 2002), including the composition and structure of dry sclerophyll forests (Keith 2004). Fire-response functional traits influence organism persistence across several levels of ecological organisation (individual, population, community, landscape). Fire regimes, spatial patterns and climate influence processes at all levels of organisation, and also influence each other through fire weather patterns, fuel accumulation rates and greenhouse gas emissions (Gill 2012; Keith 2012). Many of Australia's most diverse and dominant plant genera have traits that allow species to cope with fire as a disturbance, and these traits are likely to have contributed to their success and radiation (Miller and Murphy 2017).

For at least 65,000 years, Indigenous peoples and fire have co-existed in the Australian landscape (Clarkson *et al.* 2017; Ens *et al.* 2017; Fletcher *et al.* 2021). Indigenous groups have managed fire for purposes such as subsistence, ceremony and communication, and Indigenous cultural fire management continues in Australia today (Russell-Smith *et al.* 2009; McKemey *et al.* 2020b; Steffensen 2020). In southeast Australia, a renewal of cultural fire management is underway, with many Indigenous groups re-establishing cultural burning practices on Country (ancestral lands; Smith *et al.* 2018; Darug Ngurra *et al.* 2019; Neale *et al.* 2019a; Weir and Freeman 2019). There are many benefits associated with the renewal of Indigenous cultural fire management in southeast Australia (Maclean *et al.* 2018). Ecological benefits include: regenerating and restoring ecosystems; maintaining or improving biodiversity values; maintaining micro-climates by protecting the canopy and root systems of plants; providing benefits over moderate or high-severity, extensive burns; and providing management at a local place-based scale (Lehman 2001; Eriksen and Hankins 2014; Robinson *et al.* 2016; Maclean *et al.* 2018; Spurway 2018; Bardsley *et al.* 2019; Darug Ngurra *et al.* 2019; Kerr 2019; Weir and Freeman 2019; McKemey *et al.* 2020b). Furthermore, cultural burning may provide wildfire management benefits including: reducing the risk of, and destruction caused by, wildfire; reducing fuel loads, and protecting infrastructure (Lehman 2001; Lindenmayer 2003; Eriksen and Hankins 2014; Maclean *et al.* 2018; Spurway 2018; Robertson 2019; Weir and Freeman 2019; Weir *et al.* 2020; McKemey *et al.* in press). However, few empirical studies have

been published to evaluate these benefits (McKemey *et al.* 2020b). Consequently, Indigenous cultural fire managers have welcomed collaborative research that assesses the impact of cultural fire management (Firesticks Alliance 2020).

In the New England Tablelands of New South Wales (NSW), the Banbai Aboriginal Nation own and manage Wattleridge Indigenous Protected Area (IPA). From 2009, Banbai rangers started to reintroduce cultural fire management to their Country. The Banbai rangers, Indigenous fire practitioners and non-Indigenous scientists worked together to understand changes associated with reintroducing cultural burning to a long unburnt ecosystem. Cross-cultural research included monitoring of a cultural keystone species, the short-beaked echidna (*Tachyglossus aculeatus*) (McKemey *et al.* 2019b) and threatened plant species, the Backwater grevillea (*Grevillea scortechinii* subsp. *sarmentosa*) (McKemey *et al.* in press), as well as the co-production of a Banbai fire and seasons calendar (McKemey and Banbai Nation 2020; McKemey *et al.* 2021). Detailed ecological monitoring was undertaken to consider fine-scale changes to vegetation caused by cultural burning, which is the subject of this paper.

Fire is an integral part of the ecology of many communities of the New England Tablelands (Clarke 2006). In comparison to other regions, New England dry sclerophyll forests are species-rich systems with a large percentage of the plant diversity in the woody shrub layer and a significant number of seeder species in this layer (Graham *et al.* 2014). Many studies have considered the fire response syndrome of plant species, which is a key life history trait with profound effects on post-fire population dynamics and community composition (Noble and Slatyer 1980; Gill 1981; Hunter 2003a; Clarke *et al.* 2009; Clarke *et al.* 2015). Some plant species ('seeders') are killed by fire and, after fire, rely on seedling germination and a sufficient interfire period to survive and reproduce, whilst others ('sprouters') resprout after fire from root, basal, stem or apical buds (Clarke and Knox 2002; Pausas and Bradstock 2007; Pausas and Keeley 2014). Species can vary in their fire response due to age, herbivory, fire frequency, fire intensity, other plant stresses, soil fertility, climatic events and ecotypic genetic variation (Clarke and Knox 2002). The response of a species to fire can be useful in preliminary assessment of the extirpation risk associated with a given fire regime. Maturation times of new recruits for those plants killed by fire is a critical biological variable in the context of fire regimes, because this time sets the lower limit for fire intervals that can cause local population decline or extirpation (Keith 1996).

In the New England Tablelands, Clarke *et al.* (2009) found that resprouting was present in 62% of a total of 489 taxa of woody flora, the frequency varying among habitats, growth forms and growth

forms within habitats. Sixty-three per cent of woody plants were resprouters in dry sclerophyll forests. Kitchin (2001) found that locations in the New England Tablelands with frequent fire and short inter-fire intervals displayed reduced shrub species richness and abundance, with an accompanying simplification of the structure of the vegetation community and reduced abundance of shrub species in the seed bank. Clarke (2006) proposed that fire frequency is perhaps even more important than fire response.

Too-frequent fire reduces species richness in all vegetation types, and ‘high frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition’ has been listed as a Key Threatening Process under the NSW *Biodiversity Conservation Act 2016* (Department of Planning Industry and Environment 2020c). On the other hand, many years without fire can lead to the senescence and dwindling of fire-dependent species (Williams and Gill 1995). However, these species may persist as long-lived seed banks and not necessarily be lost to the system. Consequently, the NSW government developed the *Guidelines for Ecologically Sustainable Fire Management* (Kenny *et al.* 2004), which describes fire-interval domains for broad vegetation groupings and derives fire interval guidelines or ‘thresholds’ based on broad ranging analyses of vital attribute information for vascular plant species known to occur in these vegetation groupings.

While many fire ecology studies have been undertaken in southeast Australia, no published studies have assessed the impact of Indigenous cultural burning on dry sclerophyll forest. This study aimed to compare composition, abundance and species richness of vegetation affected by a cultural burn at Wattleridge IPA and a hazard reduction burn at nearby Warra National Park. We used this case study to evaluate the potential ecological and wildfire management benefits of Indigenous cultural burning.

7.2. Methods

7.2.1. Fieldwork

Vegetation monitoring was undertaken with measurement of indicators of fire effects, pre and post-fire, in a Before–After–Control–Impact (BACI) experimental design (Underwood 1991) at Wattleridge IPA and Warra National Park (NP) (Fig. 7.1). Prior to each fire, 30 monitoring plots were established across the two locations (12 at Wattleridge IPA, 18 at Warra NP). Of the 30 plots, 15 fire treatment plots were placed in areas that were intended to be burnt according to burn plans (National Parks and Wildlife Service NSW 2015; Rural Fire Service NSW 2015) and 15 control plots were placed in areas intended to remain unburnt. Based on similar published studies, control and impact plots shared similar vegetation type (New England Dry Sclerophyll Forests; Keith 2004), soil, geology and climate (Benson and Ashby 2000; Hunter 2005). Plots were randomly placed in each zone. Plot dimensions were 20 × 20 m, as per the Department of Environment Climate Change and Water (2011) standard. In each 20 × 20 m plot (400 m² ‘large plots’), there were four nested transects of 5 m² (totalling 20 m² of ‘transects’ per plot) and five quadrats of 1 m² (small plots).

Fire history was ascertained from maps provided by NSW National Parks and Wildlife (NPWS) for Warra NP and the NSW Rural Fire Service (RFS) Prescribed Burn Plan for Wattleridge IPA (National Parks and Wildlife Service NSW 2015; Rural Fire Service NSW 2015). Warra NP has a history of frequent large fires while Wattleridge IPA was comparatively long unburnt prior to 2015 (Table 7.1).

Table 7-1 Fire history and prescribed fire threshold of vegetation plots in Wattleridge Indigenous Protected Area (IPA) and Warra National Park (NP), 1990–2015.

	Wattleridge IPA – all plots	Warra NP – impact plots	Warra NP – control plots
Time since last large fire	30 years	16 years	14 years
Number of fires that had affected plot locations 1990–2015	0	2	3
Total number fires on property 1990–2015	4	10	10
Prescribed fire threshold*	Within threshold	Within lower limit of threshold	Too frequently burnt

* Fire interval threshold based on vital attributes of plant species in broad vegetation groupings (Kenny *et al.* 2004)

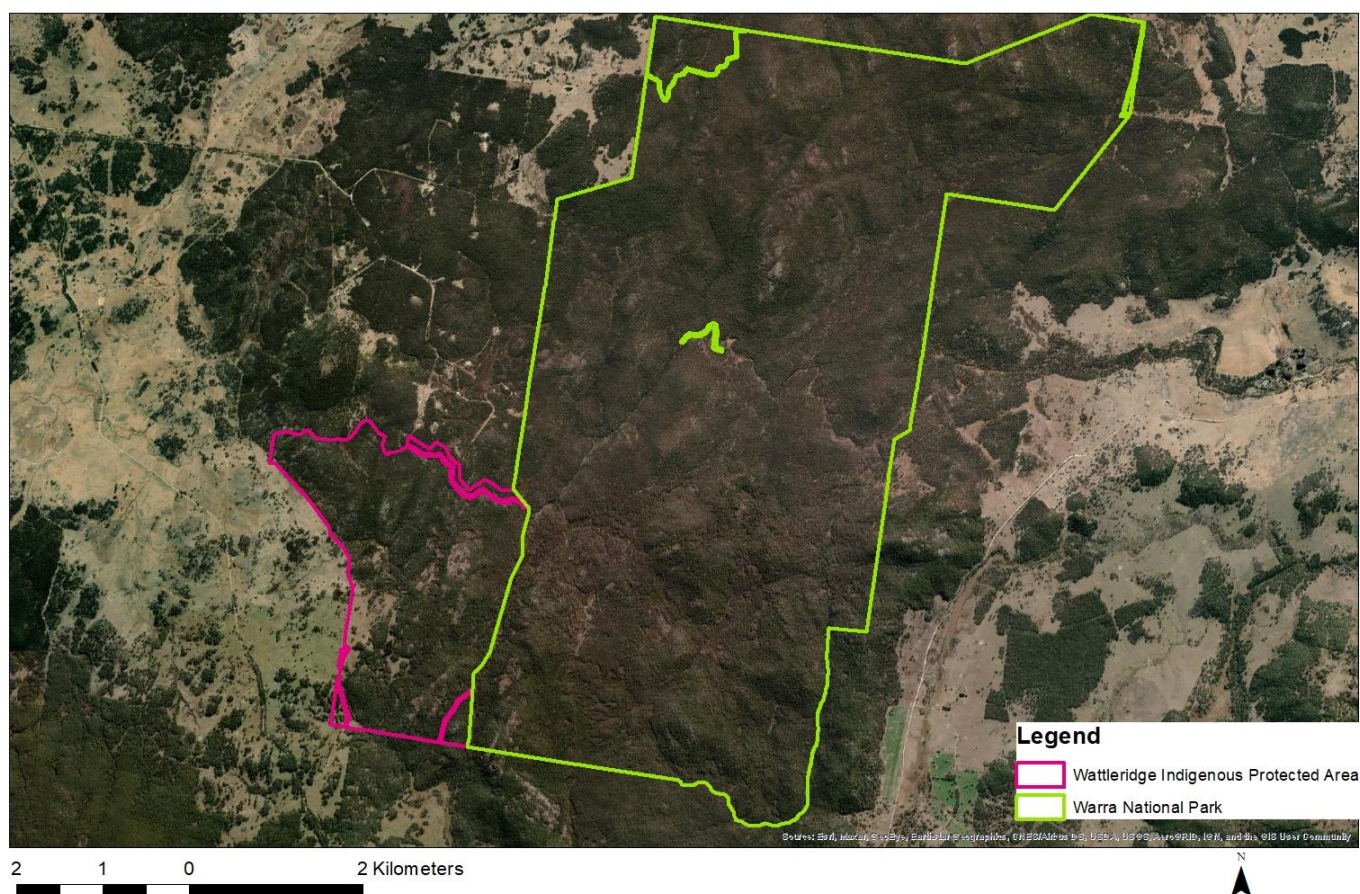


Figure 7-1 Aerial image of the study area, Wattlebridge Indigenous Protected Area, and adjoining Warra National Park in the New England Tablelands of New South Wales, Australia.

A cultural burn was undertaken by the Banbai rangers (with RFS support) at Wattlebridge IPA. This fire was a small (4 ha) low-intensity mosaic burn conducted on 16 August 2015 (late winter). A hazard reduction burn was undertaken at Warra NP and adjoining private land by NPWS and RFS. This fire was a large moderate-intensity burn conducted on 20 October 2015 (mid spring). The planned burn area was 351 ha; however, another fire started nearby and joined with the planned burn to increase the total burnt area to 685 ha.

Indicators of fire effects were measured across all plots before and at three time points (6 weeks, 1 year and 3 years) after cultural (Wattlebridge IPA) and hazard reduction (Warra NP) burning. Overall fire severity (broadly defined as ecosystem impacts from fire; Keeley 2009) was determined based on: fire plans, debrief reports, total fire size (ha), estimated canopy scorch (%) (recorded in prescribed fire debrief reports and Google Earth Engine Burnt Area Map, Department of Planning Industry and Environment 2020b), fire plan optimum intensity (intended fire intensity,

recorded in prescribed fire plans, as per National Parks and Wildlife Service NSW 2015; Rural Fire Service NSW 2015; Department of Planning 2020), observed intensity, mean percentage of plot burnt (per cent bare ground after fire in all small plots), mean tree scar height (m) (mean height of scorch on tree bole bark, visually estimated in large plots), and mean fuel load decrease (t/ha) (measured using overall fuel hazard assessment, as per Hines *et al.* 2010),

Flora nomenclature follows that of the PlantNET Information System (National Herbarium of NSW 2020, accessed 18/9/2020). For vegetation assessment, each plot was measured three times: before (2015, all plots unburned) and after fire (2016, 2018, control plots remained unburned). We identified and estimated the foliage projected cover (cover; Specht and Morgan 1981) of all plant species in the plot, and all herbaceous species in the 1m² quadrats. In the 5m² transects, total number (count) of shrubs and juvenile trees (<2 m high) was measured. For each shrub or juvenile tree, the following details were noted: number burnt/unburnt, number alive/dead, reproductive stage (none/flower/fruit) and fire response (resprouted or germinated from seed after fire). Fire response traits were allocated based primarily on direct observations of species in the post-fire environment, and secondarily from fire responses as described in Hunter (2001, 2003b) and Clarke *et al.* (2009).

7.2.2. Statistical analysis

We analysed twelve response variables (composition, cover and plot species richness of all plant species, herbaceous species, shrubs and juvenile trees; abundance of seeders, resprouters and all shrub and juvenile tree species) in relation to location (Warra NP, Wattleridge IPA), year (2015, 2016, 2018) and fire treatment (control, impact). Ordination and PERMANOVA analyses were undertaken on species cover (full floristics and just herbaceous species). Shade plots (simple visual representations of abundance matrices from multivariate species assemblage studies) were inspected in order to assess which transformation technique would be most appropriate for each dataset. For multivariate analysis, square root transformations were used with full floristic data, log (X+1) transformations were used with count data of shrubs and juvenile trees, and fourth root transformations were applied to understorey data to detect differences in composition and cover using Bray–Curtis similarity in Primer 7 (Clarke and Gorley 2015). Initial results indicated floristic separation due to location (Warra vs Wattleridge), so ordination and PERMANOVA analyses were undertaken separately for each location with plot nested within treatment and year of survey using 999 permutations to test for interactions and pair-wise tests of treatment and year. Ordinations were used to check for outliers and for general inspection of the data. No plots were identified as outliers.

Univariate modelling was undertaken on species count data to detect differences in plot species richness using R statistical software (R Core Team 2014). Data for shrub and juvenile tree, seeder and resprouter abundance were log (X+1) transformed. Analyses of variance (ANOVA) were undertaken with both locations together and separately but as the results were similar, only those with locations together are presented in the results. Univariate modelling was undertaken on plant count data to detect differences in abundance of shrubs and juvenile trees. One control plot at Wattleridge did not contain any shrubs, so this was removed from the analysis of shrub counts. Univariate modelling was undertaken on seeder and resprouter count data to determine the fire response of shrubs and juvenile trees with different life history traits. Post-hoc tests (Tukey's Pairwise Test) were conducted in PAST 4.03 (Harper and Ryan 2001) to determine differences in full floristics species richness between location and year.

7.3. Results

The fire effects in 2015 were assessed as overall low severity at Wattleridge IPA and moderate severity at Warra NP (Table 7.2). The cultural burn undertaken by Banbai rangers at Wattleridge IPA was smaller, patchier and less intense than the hazard reduction burn undertaken by NPWS at Warra NP in 2015 (described in detail in McKemey *et al.* in press).

Initial ordination of the cover and composition of the full floristic dataset (all years) indicated that the plots in Warra NP and Wattleridge IPA formed two distinct groups. This floristic separation was supported by PERMANOVA ($p = 0.009$). Therefore, we undertook PERMANOVA analysis of the two datasets separately based on location. There was no significant effect of fire on full floristic cover and composition (PERMANOVA, Year * Fire treatment: $p = 0.988$ for Warra NP, and $p = 0.938$ for Wattleridge IPA, Table 7.3). Treatment, however, was weakly significant for Wattleridge IPA (PERMANOVA, $p = 0.046$), suggesting a systemic difference between control and treatment plots. Plots averaged between 48 and 56 species at both locations, except for Wattleridge control plots, which had a mean of 38–45 species per plot. Overall, there was no evidence of a fire effect on full floristic species richness (ANOVA, Year * Fire treatment: $p = 0.914$, Table 7.4, Fig. 7.2) although the effect of treatment was significant at Wattleridge IPA (ANOVA, $p = 0.001$, Table 7.4).

Table 7-2 Fire effects and overall severity in impacted plots for the Wattleridge IPA cultural burns (August 2015) and Warra NP hazard reduction burn (October 2015). Data for fuel load decrease, tree scar height and percentage of plot burnt are mean values $\pm$ 1 SE (n). The mean fuel load decrease and tree scar height did not differ significantly between the two types of fire. Percentage of the plot burnt differed significantly at $p < 0.05$.

Indicator	Wattleridge IPA cultural burn	Warra NP hazard reduction
Mean fuel load decrease (t/ha)	8.9 ± 1.59 (6)	7.8 ± 1.49 (9)
Mean tree scar height (m)	3.8 ± 0.65 (6)	5.8 ± 1.25 (9)
Mean percentage plot burnt (%)	59 ± 8.0 (6)	81 ± 5.1 (9)
Total fire size (ha)	4	685
Fire plan optimum intensity	Low*	Moderate-high*
Observed intensity	Low	Moderate
Estimated crown scorch	0%	10%
Overall fire severity	Low	Moderate

*Fire plan optimum intensity uses the definitions in Rural and Land Management Group (2012: 17, 20) *Australasian Fire Authorities Council Bushfire Glossary* of low intensity fire as 'a fire which travels slowly and only burns lower storey vegetation, like grass and lower tree branches, with an average intensity of less than 500 kW.m^{-1} and flame height less than 1.5 m. Usually causes little or no crown scorch and is easily controlled' and high intensity fire as 'fires with an average intensity greater than 3000 kW.m^{-1} and flame heights greater than 3 m, causing complete crown scorch or possibly crown fires in forests'.

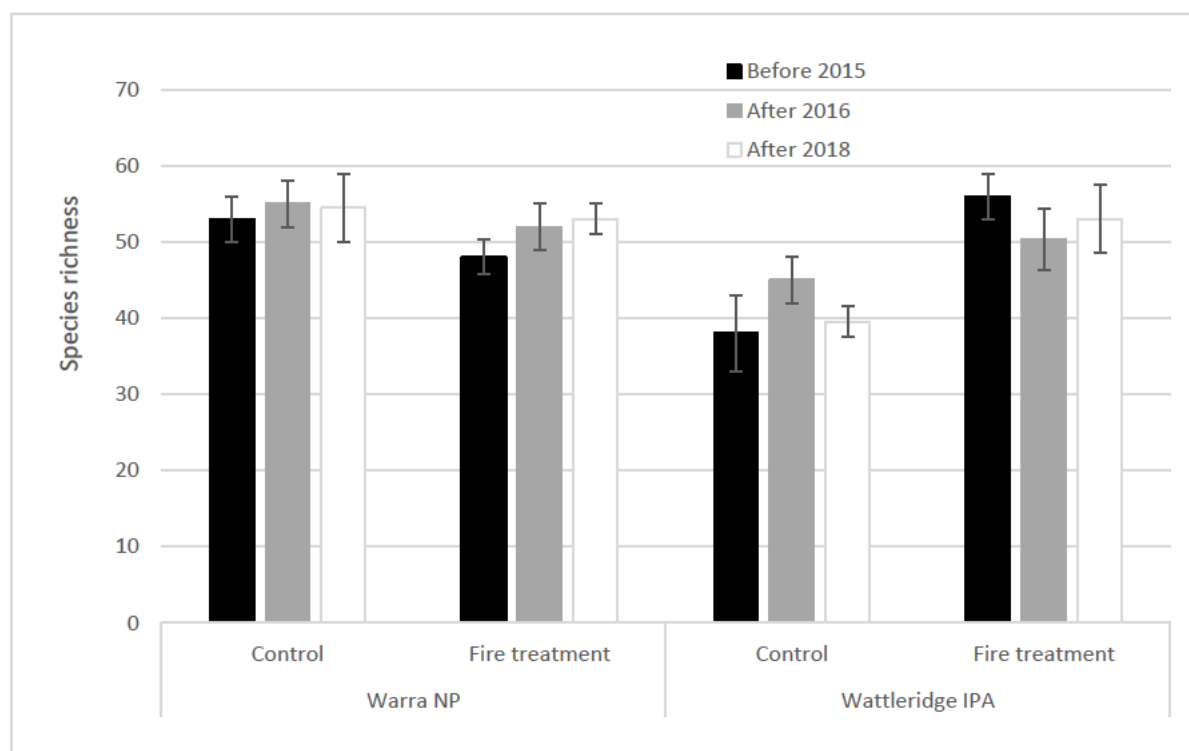


Figure 7-2 Mean species richness ($\pm$ 1 SE) of control and fire treatment (impact) plots for full floristics at Warra National Park and Wattleridge Indigenous Protected Area before (2015) treatment and 1 and 3 years (2016 and 2018) after treatment.

Herbaceous species richness was higher at Warra NP (23–26 mean number of species per plot) than Wattleridge (17–24 mean number of species per plot) (ANOVA, Location, $p < 0.0001$, Table 7.4, Fig. 7.3). Herbaceous species richness in control plots was again lower at Wattleridge than fire treatment plots (control: 17–20, treatment: 22–24). Fire did not have a significant effect on herbaceous cover and composition (PERMANOVA, Year * Fire treatment: $p > 0.8$, Table 7.3) but year 2015 was significantly different to years 2016 and 18 at Warra NP (PERMANOVA, Year: $p = 0.0001$, Table 7.3).

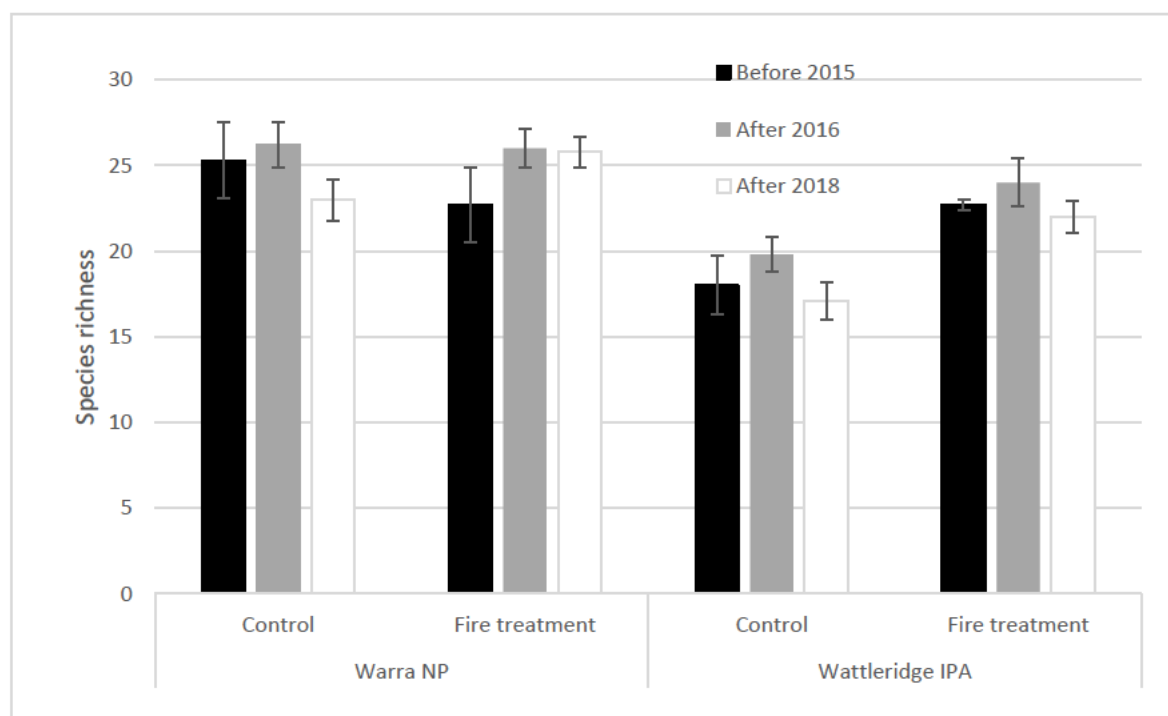


Figure 7-3 Mean herbaceous species richness (± 1 SE) at Warra National Park and Wattleridge Indigenous Protected Area in control and Fire treatment (impact) plots before treatment in 2015 and 1 years and 3 years (2016 and 2018) after treatment.

There was higher richness of shrub and juvenile tree species at Wattleridge IPA (mean of 7–13 species) than Warra NP (4–10) (Fig 7.4). The impact of fire on shrub and juvenile tree cover and composition was significant at Warra NP immediately after the hazard reduction burn (PERMANOVA, Year * Fire treatment: 2015 vs 2016, $p = 0.002$, Table 7.3) but not at Wattleridge IPA. The following species, which were mostly observed to be seeders, increased in abundance: *Bossiaea scortechinii*, *Acacia filicifolia*, *Eucalyptus* sp., *Dillwynia retorta*, *Hovea purpurea* and *Grevillea scortechinii* subsp. *sarmentosa*. In contrast, the following species, which were mostly observed to resprout, decreased in abundance: *Indigofera australis*, *Bursaria spinosa*, *Leucopogon lanceolatus* and *Brachyloma daphnoides*. The impact of fire on shrub and juvenile tree species richness was not significant ($p = 0.259$). However, the effect of both Location and Year on woody species richness was significant (Table 7.4), with the richness of shrubs and juvenile trees being

lower in 2015 than in subsequent years and lower overall in Warra NP than Wattleridge IPA (Fig. 7.4). One year after fire, shrub and juvenile tree abundance increased significantly in the burnt plots at both Warra NP and Wattleridge IPA (ANOVA, Year * Fire treatment: $p < 0.0001$, Table 7.4, Fig. 7.5).

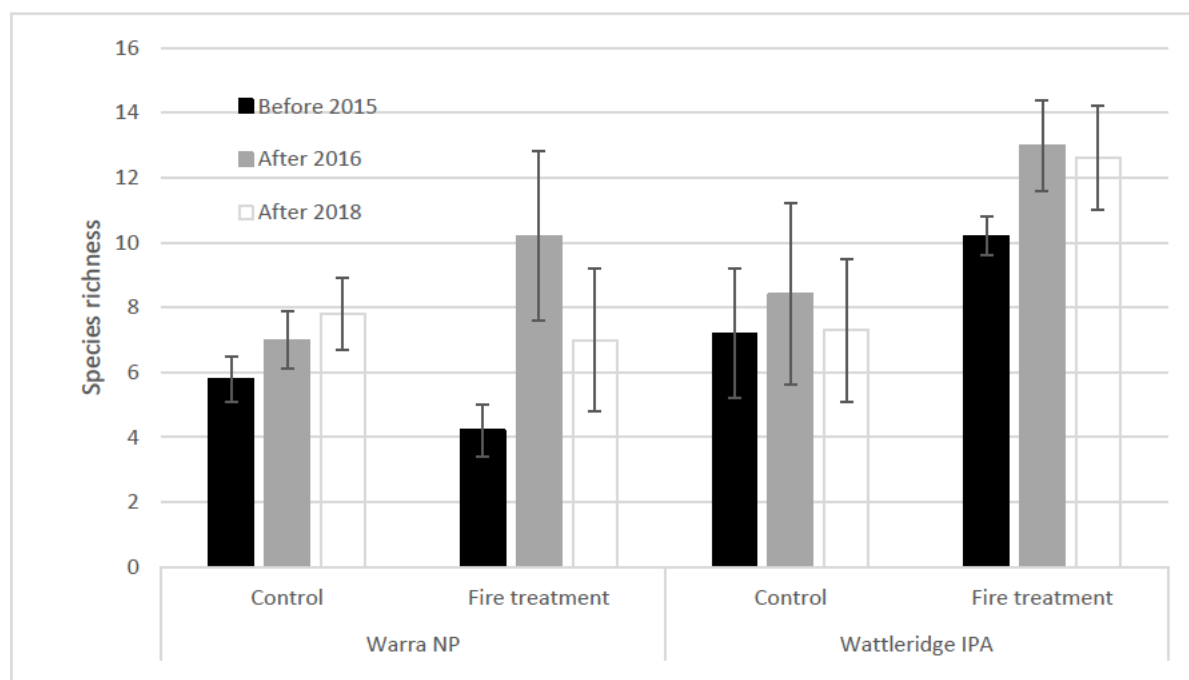


Figure 7-4 Mean species richness (± 1 SE) of shrubs and juvenile trees at Warra National Park and Wattleridge Indigenous Protected Area in control and fire treatment (impact) plots before (2015) treatment and 1 year and 3 years (2016 and 2018) after treatment.

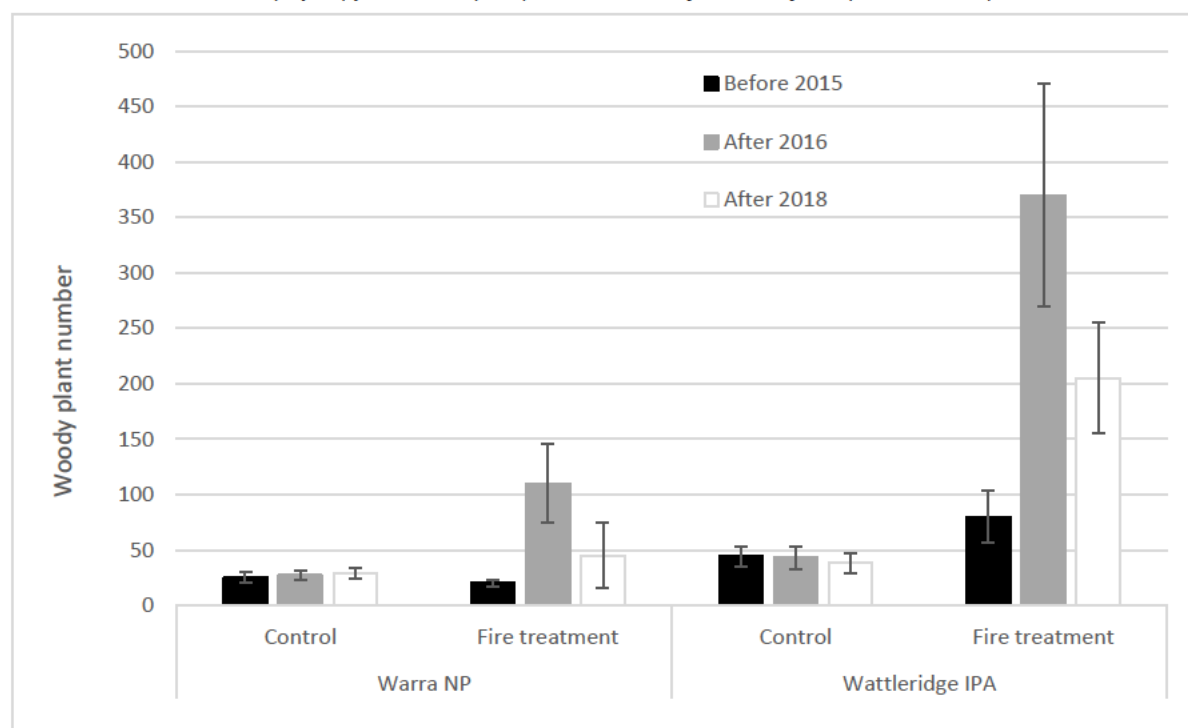


Figure 7-5 Mean shrub and juvenile tree abundance (± 1 SE) at Warra National Park and Wattleridge Indigenous Protected Area in control and fire treatment (impact) plots before treatment (2015) and 1 year and 3 years (2016 and 2018) after treatment.

A higher number of shrub and tree species were seeders at Wattleridge (seeders = 24, 67%; resprouters = 12, 33%) than at Warra (seeders = 18, 55%; resprouters = 15, 45%). Following fire treatments, seeder abundance increased significantly in 2016 (ANOVA, $p = 0.001$, Table 7.4, Fig 7.6a). Resprouter abundance was not significantly affected by fire treatment (ANOVA, $p > 0.08$, Table 7.4, Fig 7.6b). Fire response traits for each species are listed in Appendix 7.1.

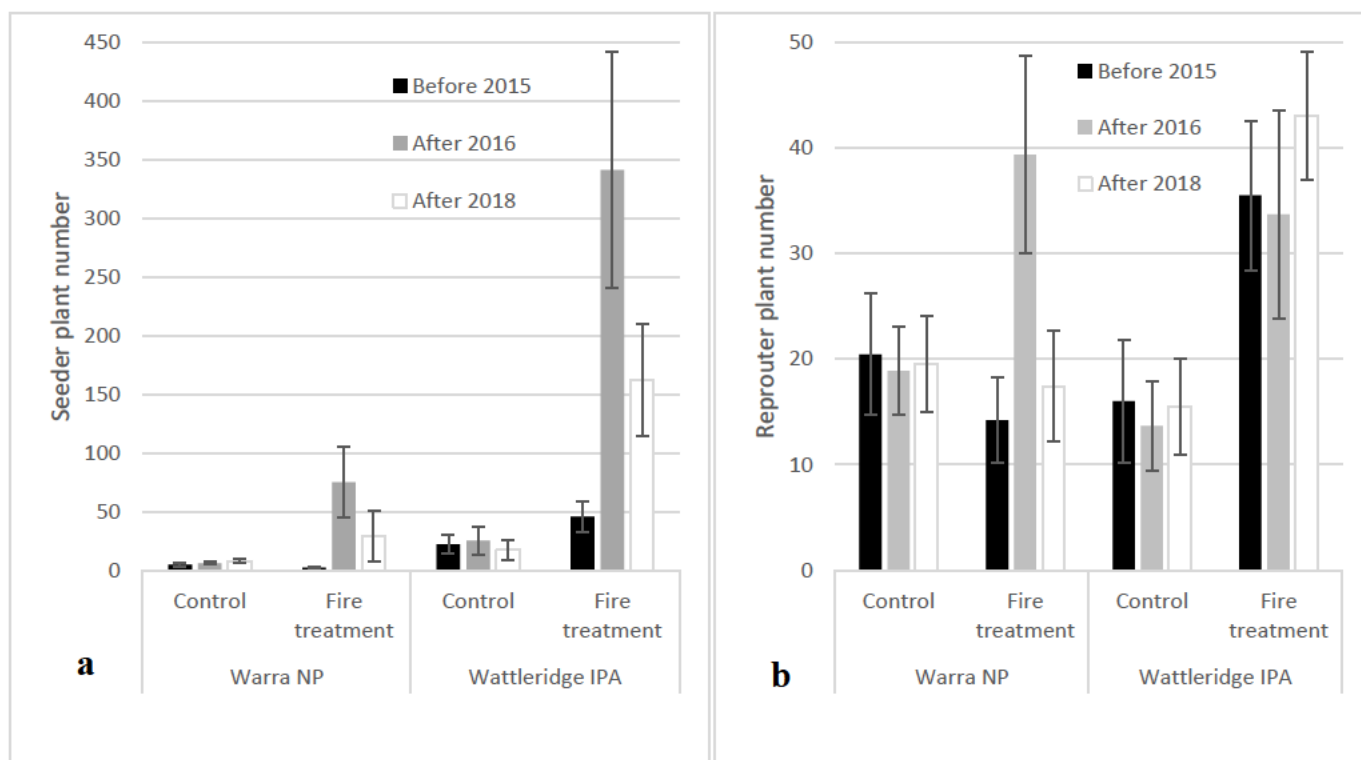


Figure 7-6 Mean seeder (a) and resprouter (b) plot abundance (± 1 SE) at Warra National Park and Wattleridge Indigenous Protected Area in control and fire treatment (impact) plots before treatment (2015) and 1 year and 3 years (2016 and 2018) after treatment.

Table 7-3 Summary of the results of vegetative cover and composition (PERMANOVA) analyses.

Plant taxa	Location	Year	Fire treatment	Year * Fire treatment
Full floristics	Warra NP	0.175	0.115	0.988
	Wattleridge IPA	0.459	0.046	0.938
Herbaceous species	Warra NP	0.0001	0.110	0.828
	Wattleridge IPA	0.087	0.101	0.978
Shrubs and juvenile trees (<2 m high)	Warra NP	0.02 (2015 v 16 = 0.003)	0.031	0.353 (Impact plots, 2015 v 16 = 0.002)
	Wattleridge IPA	0.983	0.014	0.975

Table 7-4 Summary of the results of univariate (ANOVA) statistical analyses of plant taxa, full floristics, herbaceous species and shrubs and juvenile trees showing p-values for main effects and interactions.

Plant taxa	Response variable	Location	Year	Fire treatment	Year * Fire treatment
Full floristics	Plot species richness	0.086	0.734	Overall= 0.005 (Warra NP = 0.941, Wattleridge IPA = 0.001 ⁺)	0.914
Herbaceous species	Plot species richness	8.38e-06	0.289	0.895	0.120
Shrubs and juvenile trees (<2 m high)	Plot species richness	5.1e-05	0.0160	0.110	0.259
	Abundance	1.33e-09	0.952	0.591	2016 = 6.27e-05 2018 = 0.054
	Seeder abundance	9.93e-10	0.716	0.922	2016 = 0.001 2018 = 0.094
	Resprouter abundance	0.016	0.863	0.999	2016 = 0.085 2018 = 0.594

⁺ Only Control vs Impact in 2015, Tukey's Pairwise Test

7.4. Discussion

The study found that overall low severity cultural burning and moderate severity hazard reduction burning did not have a significant impact on the full floristic composition, cover or richness of the vegetation or on the herbaceous layer in the 1 to 3 years after fire. Similarly, other studies of the ecological effects of low to moderate severity prescribed burning in dry sclerophyll forests in southeast Australia found that plant cover, abundance and species richness were not significantly affected in the long term (Purdie and Slatyer 1976; Tolhurst *et al.* 1992; Watson and Wardell-Johnson 2004).

Only the higher severity hazard reduction burn had a significant impact on shrub and juvenile tree cover and composition. Species richness of shrub and juvenile trees was greater at Wattleridge IPA than at Warra National Park. Shrub and juvenile tree abundance increased at both locations due to fire, more so at Wattleridge IPA where it remained elevated three years after the cultural burn. This may have been driven by a few species that were more common at Wattleridge IPA (e.g. *Hovea purpurea* and *Grevillea scortechinii* subsp. *sarmentosa*) and probably due to a higher quantity of soil-stored seed due to the comparatively long unburnt status of the vegetation at Wattleridge IPA (i.e. >30 years). In contrast, shrub and tree species at Warra NP may have had depleted seed reserves due to the greater frequency of recent fire (Tolhurst *et al.* 1992; McKemey *et al.* in press), resulting in the lower abundance of shrubs and juvenile trees at Warra NP. This corroborates Kitchin (2001) finding that frequent fire and short inter-fire intervals were associated with reduced shrub species and seed bank richness and abundance at nearby Guy Fawkes River National Park in northern NSW.

Other studies have found that time since fire affects species composition and plant functional type (Duff *et al.* 2013; Gosper *et al.* 2013). Chick *et al.* (2016) found a weak positive relationship between seed bank richness and time since fire in heathy woodland ecosystems in Victoria, which may suggest that seed bank diversity could accumulate over time. However, in the study by Chick *et al.* (2016), spatial and environmental variability had more influence on seed bank composition. The present study also found that other variables affected some results, such as year. This suggests that under certain circumstances, year (including variables such as rainfall) may have a larger effect on variables such as species richness, than fire.

On the New England Tablelands Clarke *et al.* (2005) found partial support for a fire frequency disturbance model, which predicted that ‘resprouting will be more frequent in landscapes with

higher probabilities of frequent fire'. Clarke *et al.* (2009) found that 63% of woody plants were resprouters in New England dry sclerophyll forests whereas our study found that 33% were resprouters at Wattleridge IPA and 45% at Warra NP. At a broader scale, the hypothesis that resprouting is positively correlated with fire frequency or intensity has been supported by some studies (Bradstock and O'Connell 1988; Morrison *et al.* 1995; Vesk and Westoby 2004; Lamont *et al.* 2011) but not others (Clarke *et al.* 2015). Clarke *et al.* (2009) suggested that resprouting is a labile trait that varies within genera and even within species, due to environment or genotype.

As we have pointed out, the long unburnt fire regime at Wattleridge IPA may have made vegetation communities more responsive to fire than the more frequently burnt vegetation at Warra NP, such that the mosaic cultural burn had a greater impact on woody species. When comparing cultural burning to other fire treatments, results need to be considered carefully within the specific contexts of each treatment. A frequently burnt ecosystem may not respond with a large change despite a larger, more severe fire, whereas a patchy, low severity fire may have a greater impact in a long unburnt ecosystem where plant species with a 'seeder' fire response have increased in frequency over time. Therefore fire history and regime is an important consideration when interpreting research results and planning for fire management.

In December 2019, the very large (9091-ha) high severity Crown Mountain wildfire burnt all of the control and impact BACI plots at Wattleridge IPA and Warra NP. This provides an opportunity to compare the impact of the wildfire on the variables addressed in this paper, and to compare the severity and impacts of wildfire in the long unburnt control plots with high fuel loads, compared to the 2015 culturally burnt plots with lower fuel loads. McKemey *et al.* (in press) studied the impact of cultural burning on the threatened Backwater grevillea, *Grevillea scortechinii* subsp. *sarmentosa*, at Wattleridge IPA, and found that cultural burning had a lesser impact on mature grevillea survival than the wildfire. The cultural burn created a multi-age population in culturally burnt sites, with mature surviving shrubs contributing to the seed bank and seedlings providing the next generation of grevilleas. It would be worthwhile to extend this investigation to other species in this study.

This study was an attempt to address the research gap related to the quantitative ecological assessment of Indigenous cultural burning in southeast Australia. Cultural burning has been asserted to provide ecological and wildfire management benefits, as described in the Introduction (Section 7.1) and Chapter 2. This study, although a single case-study, provides support for some of these claims. For example, we found that both cultural burning and hazard reduction burning decreased fuel loads. Although the Crown Mountain wildfire subsequently burnt both Warra NP

and Wattleridge IPA in 2019, it is unlikely that any program of prescribed burning could have prevented the unprecedented, extreme ‘Black Summer’ wildfires of 2019–20 (Penman *et al.* 2011; Tolhurst and McCarthy 2016; Department of Planning Industry and Environment 2020b; Filkov *et al.* 2020; Wintle *et al.* 2020; McKemey *et al.* in press). Our study found that the low severity cultural burn did not significantly impact full floristics or herbaceous species, but stimulated the regeneration of seeder shrubs and trees. The cultural burn in 2015 could potentially have depleted the seed bank and the regenerative reserves of resprouters, which would then have been further diminished by the wildfire in 2019. Frequent fire can result in the disruption of life-cycle processes in plants and loss of vegetation structure and composition (Department of Planning Industry and Environment 2020c), so future fire planning by the Banbai rangers should take into account these potential impacts on population viability of the constituent species in the Wattleridge IPA vegetation. The ecosystems and biodiversity values at Wattleridge IPA were in good condition prior to cultural burning (Benson and Ashby 2000; Hunter 2003b), so restoration of ecosystems could not be demonstrated in this study. Banbai rangers undertook cultural burning through a cultural management framework, which allowed Indigenous custodians to conserve biodiversity using culturally driven, holistic management that was locally focused and supported by cross-cultural knowledge (McKemey *et al.* in press). Banbai cultural fire management afforded an array of cultural benefits, as discussed in McKemey *et al.* (2019b); McKemey *et al.* (2021); McKemey *et al.* (in press). In terms of ecological and wildfire management outcomes, this study provides evidence to support claims that cultural burning decreases fuel loads, stimulates regeneration of seeder shrubs and trees, and provides management at a local place-based scale, while not significantly impacting full floristics or the herbaceous vegetation layer.

7.5. Conclusion

Similar to other studies, our study found that low and moderate severity burns did not have significant impacts on full floristics or the herbaceous layer over a 3-year period in dry sclerophyll forest on the New England Tablelands in northern NSW, but the cultural burn did stimulate a mass germination event for woody seeders. This emphasises the importance of considering fire history when comparing the impacts of various fire treatments. Through this case study, we provide empirical evidence that supports claims that Indigenous cultural burning provides ecological and wildfire management benefits.

**Higher Degree Research Thesis by Publication
University of New England**

STATEMENT OF AUTHORS' CONTRIBUTION

We, the PhD candidate and the candidate's Principal Supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the candidate's contribution as indicated in the *Statement of Originality*.

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Name/title of Principal Supervisor: Prof. Nick C. H. Reid



16/11/2020

Candidate

Date



17/11/2020

Principal Supervisor

Date

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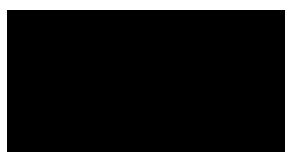
STATEMENT OF ORIGINALITY

We, the PhD candidate and the candidate's Principal Supervisor, certify that the following text, figures and diagrams are the candidate's original work.

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Name of Candidate: Michelle McKemey

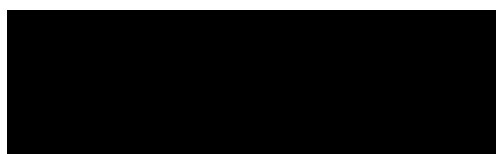
Name/title of Principal Supervisor: Prof Nick Reid



16/11/2020

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Principal Supervisor

Date

Chapter 8. Synthesis and conclusions

Australia is at a unique juncture, having recently endured ‘unprecedented’ catastrophic wildfires (Filkov *et al.* 2020; Nolan *et al.* 2020; Wintle *et al.* 2020) and, as a fire-prone continent, being amongst the first to experience the effects of the Pyrocene (Pyne 2020). Australian society is beginning to acknowledge Australia’s deep past as home to Indigenous peoples for millennia, resulting in today’s heavily curated cultural landscape (Bowman 2003b; Russell-Smith *et al.* 2009; Gammage 2011; Pascoe 2014; Clarkson *et al.* 2017; Ens *et al.* 2017; Mawson 2020; Fletcher *et al.* 2021). The growth of Indigenous caring for Country programs, cross-cultural partnerships and renewal of cultural burning, places Indigenous peoples, supported by ‘right-way’ science, in a unique position to contribute to solving some of the challenges associated with fire management this century (Morrison 2020). Australian Indigenous groups have gained international recognition for their successful fire management programs and supported other Indigenous groups in Botswana, Canada and Brazil (Dann and Woodward 2020). Indigenous fire management could be applied to many other regions around the world (Lipsett-Moore *et al.* 2018) as could Indigenous-led biodiversity conservation and research (Tengö *et al.* 2017).

This thesis investigated ways in which Indigenous rangers and non-Indigenous scientists can work together to co-produce cross-cultural knowledge (‘right way’ science) to support Indigenous cultural fire management. I provided case studies of ethical, productive and mutually beneficial research partnerships with the Banbai and Yugul Mangi peoples, and shared their biocultural knowledge related to fire, seasons and Country. Together, the Banbai rangers and I shared the story of cultural fire renewal undertaken by their community in a post-colonial nation-state where fire management has been altered since European settlement. Furthermore, the research generated quantitative and qualitative evidence to consider the impacts of cultural burning on ecological and cultural values. In this concluding chapter, I provide a summary of: the main findings in relation to my research objectives; my contribution to current theoretical and practical knowledge; the limitations of the research; recommendations for future research; and my thesis conclusions.

8.1. Summary of main findings

Objective 1: To describe the current status of Indigenous cultural fire management in southeast Australia

I undertook a systematic analysis of the literature in order to describe the current status of Indigenous cultural fire management in southeast Australia. Seventy documented contemporary cultural fire management projects were found for southeast Australia, with the potential for significant upscaling. Over the last decade, eight policies related to Indigenous fire management have been developed by state and territory governments in southeast Australia, with varying levels of implementation. Seventy-eight benefits and 22 barriers were identified in relation to cultural fire management. In the cases where cultural fire management has been successfully reinstated as an ongoing practice, Indigenous leadership, extraordinary relationships, strong agreements and transformational change were identified as drivers of success. For cultural fire management to grow, more funding, policy implementation, long-term commitment, Indigenous control and decision making, mentoring, training and research are required. Several areas of research could facilitate the expansion of cultural fire management and be applied in similar contexts globally, including the Americas and Africa. While Indigenous voices are increasingly represented in the literature, it is imperative that mutually beneficial and respectful partnerships are developed in the cross-cultural interface of landscape fire management.

Objective 2: To provide case studies of Indigenous cultural fire management for the Yugul Mangi people at South East Arnhem Land IPA (NT) and Banbai people at Wattleridge IPA (NSW). To consider how Indigenous biocultural knowledge and various other knowledges (archaeological, ethnohistorical, ecological, cross-cultural and local) can be used to inform contemporary cultural fire management, for example, through the co-development of fire and season calendars intended to guide cultural burning

In Chapter 3, I provided a case study of the Yugul Mangi rangers' fire management in the SEAL IPA. I undertook participatory action research and semi-structured interviews with rangers and Elders during 2016 and 2019 to investigate Indigenous knowledge and obtain local feedback about fire management. Results indicated that Indigenous rangers effectively use cross-cultural science (including local and Traditional Ecological Knowledge alongside Western science) to manage fire. Fire management is a key driver in the production of bush tucker (wild food) resources and impacts other cultural and ecological values. A need for increased education and awareness about

Indigenous burning was consistently emphasised. To address this, we co-produced the *Yugul Mangi Faiya En Sisen Kelenda* (Yugul Mangi Fire and Seasons Calendar) that drew on Indigenous knowledge of seasonal biocultural indicators to guide the rangers' fire management planning. The calendar has potential for application in fire management planning, intergenerational transfer of Indigenous knowledge and locally driven adaptive fire management.

Through this study, it was demonstrated that many Indigenous communities have traditional ecological and seasonal knowledge, and are increasingly documenting this knowledge in seasonal calendars. However, in southeast Australia, the impacts of European colonisation were severe and many Indigenous communities were prevented from continuing their traditional fire practices or passing on their knowledge. In Chapter 6, I synthesised evidence from various knowledges (archaeological, ethnohistorical, traditional Indigenous, ecological, cross-cultural and local) to support Banbai rangers in the co-production of a fire and seasons calendar to inform contemporary cultural fire management at Wattleridge IPA. 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. This process of co-producing knowledge, revitalising culture and caring for Country is relevant for many Indigenous communities around the world.

Objective 3: To use cross-cultural methods to assess how the culturally significant echidna and threatened Backwater grevillea respond to cultural burning

In Chapter 4, I described the process that the Banbai people went through to reintroduce cultural burning at Wattleridge IPA. Our team of Banbai rangers and non-Indigenous scientists conducted cross-cultural research to investigate the impact of burning on a cultural keystone species, the echidna. A comparison of the effects of a low-intensity, patchy, cultural fire in the Wattleridge IPA to a nearby higher intensity fire in Warra National Park through a Before–After–Control–Impact (BACI) assessment indicated that the higher intensity fire reduced echidna foraging area, presumably due to predator avoidance by echidnas. Most importantly, a cross-cultural research model was described where Indigenous rangers and non-Indigenous scientists worked together to inform adaptive natural and cultural resource management. Such trans-disciplinary and collaborative research strengthened and informed conservation decision making and the social–ecological resilience of the Banbai community.

In Chapter 5, Banbai rangers and I used cross-cultural methods and BACI design to monitor the impact of cultural burning versus wildfire on the threatened plant, Backwater grevillea (*Grevillea*

scortechinii subsp. *sarmentosa*). Cultural burning resulted in lower mature grevillea mortality and lesser impact on reproductive output than wildfire. Both fires stimulated a mass germination event but the cultural burn preserved a multi-aged population while the wildfire killed 99.6% of mature shrubs. Our case study of the Backwater grevillea and its Banbai custodians provides an example where Indigenous rangers have adopted a plant into their cultural management framework. They are conserving this threatened species using culturally driven holistic management that is locally focused and supported by cross-cultural knowledge.

Objective 4: To compare the effects of, and fuel hazard changes associated with, various fire management treatments. These include: Indigenous cultural burning, a National Park and Wildlife Service NSW (NPWS) hazard reduction burn, and a wildfire

In Chapters 2–6, Indigenous rangers explained the characteristics of cultural burning, and how it contrasts with hazard reduction burning and wildfire. In Chapter 5, a quantitative assessment of various fire effects was undertaken, and found that cultural burning was low severity at Wattleridge IPA, hazard reduction burning was moderate severity at Warra NP and the Crown Mountain wildfire was a very high severity crown fire at both locations. Our comparison of fuel load changes resulting from cultural burning, hazard reduction burning and wildfire indicated that fuel loads were reduced by all fire treatments, even though the cultural burn was less severe than other fires.

Objective 5: To compare the impact of a cultural burn with a hazard reduction burn on dry sclerophyll forest vegetation composition, cover, abundance and species richness

In Chapter 7, the impact of the Banbai rangers' cultural burn at Wattleridge IPA on the composition, cover, abundance and species richness of dry sclerophyll forest was compared with a hazard reduction burn at Warra National Park, using the BACI experimental design. The study found that the low-severity cultural burn and moderate-severity hazard reduction burn reduced fuel loads but did not have a significant impact on full floristics or herbaceous vegetation. Only the hazard reduction burn had a significant impact on shrub and juvenile tree (woody species) cover and composition. The abundance of woody species was significantly affected by both fires, due to a mass germination of 'seeder' species, particularly after the cultural burn. The long unburnt fire regime at Wattleridge IPA may have made vegetation communities more responsive to fire than the more frequently burnt vegetation at Warra National Park, such that the mosaic cultural burn had a greater impact on woody species abundance. In terms of ecological and wildfire management outcomes, this study provided evidence to support claims that Indigenous cultural burning

decreases fuel loads, stimulates regeneration of shrubs and trees, and provides management at a local, place-based scale.

Objective 6: To synthesise the findings of the research to: assess the outcomes of cultural burning in relation to its stated benefits; demonstrate how cross-cultural knowledge can support Indigenous cultural fire management and biodiversity conservation; and consider the broader benefits and potential applications of collaborative cross-cultural approaches.

In Chapter 2, many of the benefits of cultural burning were documented. However, quantitative studies of these benefits were under-represented. In general, Indigenous fire practitioners in southeast Australia claim that cultural burning is smaller, patchier and less severe than other fire types (e.g. hazard reduction burning or wildfire). They assert that the forest canopy is sacred and must not be burnt under Indigenous cultural burning Lore, and that cultural burning leaves habitat for animals, protects special places, encourages regeneration and helps to prevent destructive wildfires. This study provided data to support these claims. Chapter 4 presented support for the claim that cultural burning leaves habitat for animals: cultural burning did not significantly affect litter depth and log length, nor did it significantly change the foraging activity of the echidna at Wattleridge IPA. In Chapter 5, the fire effects of cultural burning, hazard reduction burning and wildfire were compared. This study supported many of the claims of Indigenous fire practitioners, including: cultural burning reduces fuel loads (to a similar level as hazard reduction and wildfire); wildfires are larger, more severe and more destructive than cultural burning, and cultural burning is patchier than hazard reduction and wildfire. This study found that cultural burning did not impact the canopy while wildfire affected 90% of the canopy. Cultural burning promoted regeneration of the threatened Backwater grevillea and ‘seeder’ shrubs and trees. A significant cultural heritage site, Indigenous rock art at Kukra Hill at Wattleridge IPA, was not damaged by wildfire due to previous cultural burning and the protective actions of the Banbai rangers during the Crown Mountain bushfire (McKemey 2020b). I believe this is the first published scientific study in southeast Australia to quantitatively analyse many of the benefits of cultural burning described here.

This study also contributed qualitative evidence of some of the benefits of cultural burning, including: the sharing and communication of Indigenous biocultural knowledge for fire management; intergenerational transfer of Indigenous biocultural knowledge; the revitalisation of Banbai culture and enhanced connection to Country; use of threatened Indigenous languages; capacity building for rangers and scientists; development of long-term research partnerships and

cross-cultural monitoring programs, and conservation of a culturally significant animal and threatened plant through a cultural management framework.

We have started down the path of providing the scientific evidence to support or improve Indigenous cultural fire management. This is a long-term journey that will need to be undertaken over many years. We have described a landscape-scale Indigenous fire management project in the SEAL IPA that has been demonstrated to deliver social, economic, ecological and cultural benefits, and how cross-cultural science is supporting this initiative. We have described the barriers and benefits to cultural burning in southeast Australia and shown there is a great deal of interest from Indigenous communities and the broader (global) public (Chapter 2) in renewing cultural burning. We have described the process whereby the Banbai rangers in NSW reintroduced cultural burning and renewed their cultural fire knowledge and provided several examples where cross-cultural science was used to support this practice. This demonstrates that cultural fire knowledge and practice is alive in southeast Australia, contrary to the findings of previous bushfire inquiries (Esplin *et al.* 2003; Neale *et al.* 2020a). We have demonstrated a process whereby the practice and knowledge of cultural fire management was able to be renewed. Prescribed burning has had mixed success in protecting us from wildfires and the future is potentially dire (Peterson *et al.* 2011; Pyne 2019; Filkov *et al.* 2020; Mullins *et al.* 2020; Pyne 2020). However, wildfires doyen Stephen Pyne (2020) suggested that Australia is well positioned to respond to the advancing Pyrocene, through its experience, ‘fire culture’ and technological capacity. While only one component of a multi-faceted and complex issue, which must address issues such as climate change (Bureau of Meteorology and CSIRO 2020; Mullins *et al.* 2020) and disaster management (Binskin *et al.* 2020), Indigenous cultural fire management is now recognised as part of this solution in Australia (Binskin *et al.* 2020; Owens and O’Kane 2020) and globally (Kelly *et al.* 2020). Cultural burning brings not only a practice of fire management, but a holistic philosophy that underpins how land, wildlife, people and the cosmos interrelate. Rather than the extractive, commodification, enlightenment philosophy that has dominated Western resource management, in this volatile, unpredictable and deeply concerning era of the Pyrocene, Indigenous and collective wisdom offers innovative pathways to navigate towards a sustainable future

8.2. Contribution to scientific theory and practice

A diversity of views exist among Western scientists regarding the knowledge and practice of Indigenous cultural fire management in the contemporary social–ecological systems of southeast Australia. Much public interest in cultural burning relates to its potential to mitigate wildfire risk through the reduction of fuel loads (Binskin *et al.* 2020; Owens and O’Kane 2020). Academics also question where and how much Indigenous knowledge exists related to cultural fire management (Esplin *et al.* 2003; Bardsley *et al.* 2019) and how it might apply to social–ecological systems characterised by high flammability, significant assets, relatively high human population and large areas of wildland–urban interface (Bradstock 2008; Moritz *et al.* 2014). Therefore, it could be suggested that key questions raised in Australian society relate to whether cultural burning reduces wildfire risk and if there is sufficient knowledge and capacity held by Indigenous peoples to renew cultural fire management in southeast Australia.

Indigenous Australians do not necessarily share these research priorities. For example, our co-developed research questions focused on issues such as: how can communities renew cultural burning practices; how is Indigenous cultural fire management different to hazard reduction and wildfire; how does cultural burning affect key cultural and ecological values; how can we co-produce cross-cultural knowledge to inform adaptive management; and what are the broader benefits of Indigenous land and cultural fire management? Indigenous communities and organisations in southeast Australia are seeking support to produce peer-reviewed evidence that is communicated to, and can influence policy makers on, the benefits of cultural practices across a broad spectrum of policy areas (Firesticks Alliance 2020). Some communities have expressed an interest in biophysical research that can help produce useful ecological knowledge either directly for community use or as a means to attract support from government agencies for cultural burning; or research related to historical and colonial accounts of burning by Indigenous peoples that could help support localised revitalisation projects (Smith *et al.* 2018).

These research interests and priorities demonstrate a divide between cultures in terms of the focus and outcomes of research. Cross-cultural research attempts to cross this divide to provide answers that are useful to both cultures. Furthermore, cross-cultural research should aim to dismantle some of the overarching Western colonial methods (e.g. inadequate knowledge sharing protocols, misappropriation and misuse of Indigenous knowledge; Woodward *et al.* 2020) of undertaking research and encourage use of Indigenous research methods (Chilisa 2019; Chapman and Schott 2020). Neale *et al.* (2019a) and their Dja Dja Wurrung collaborators described reintroducing

cultural burning as ‘walking together’ for Indigenous peoples and settler colonial nations, through a process of iterative decolonising renovation of the political and practical dominance of settler agencies. Likewise, cross-cultural research also seeks to decolonise Western research methodologies (Section 1.2.4), through Indigenous-led and ‘knowledge co-evolution’ (Chapman and Schott 2020) approaches that strengthen and share knowledge through ethical, productive and mutually beneficial relationships (Bohensky and Maru 2011; Tengö *et al.* 2014; Tengö *et al.* 2017; Woodward *et al.* 2020). Through my engagement in cross-cultural research, I have concluded that there are a few fundamental principles that non-Indigenous people must acknowledge in order to support Indigenous peoples and practise ‘right way’ cross-cultural science. These principles include collaboration, advocacy and support rather than validation (AIATSIS 2020). In recent years, best-practice guidelines for cross-cultural research (Robinson *et al.* 2016; AIATSIS 2020; Woodward *et al.* 2020) and Indigenous priorities for cultural fire management research (Smith *et al.* 2018; Firesticks Alliance 2020) have been articulated, which provide clear direction for scientists wishing to engage in cross-cultural research.

Furthermore our research contributes to a growing voice in the academic literature that emphasises pride in Australia’s long, dynamic and deep history, uniquely shaped by Indigenous human intervention over at least 65,000 years (Gammage 2011; Pascoe 2014; Behrendt 2016; Mawson 2020). This deep history of Australia forms not only a central part of Indigenous pride in heritage and culture but also offers exciting possibilities for a future Australia (Mawson 2020). Rather than focusing only on the trauma that has accompanied centuries of dispossession and genocide, Indigenous representatives like Bruce Pascoe, Wayne Nannup and Joe Morrison argue that this offers a new future for reconciliation in Australia (Pascoe 2014; Robertson *et al.* 2016; Morrison 2020). This aligns with sentiments expressed by Bowman (2003b) that a profound understanding of the long history of fire in Australia is needed in order for modern day land managers to once again ‘tame’ fire. Calls for reinstatement of Indigenous land stewardship have been amplified by the public response following the Black Summer wildfires (Box 2.2), and evidence that the Anthropocene is quickly giving way to the Pyrocene (Pyne 2019; Mawson 2020). Mawson (2020: 23) eloquently expressed this sentiment:

Never before has the history of Australia’s deep past been so relevant and urgent to the present – a fact that invites Australians to confront the social, political, and ecological legacy of colonisation. As Pascoe argues, reconciliation is not just a matter of saying sorry for past wrongs, but also learning to say thanks: to recognize what is extraordinary, innovative, and vital

in Aboriginal economic, social, and cultural histories that radically shaped the Australian landscape over millennia.

8.3. Research limitations

This thesis has sought to investigate a wide range of issues in a multi-disciplinary space. Due to the generalist nature of attempting to cover fields of botany, zoology, fire ecology, biodiversity conservation, anthropology and Western and Indigenous research methodologies, this research was not able to delve deeply into highly specialised questions in each of these fields. For example, BACI experimental design and monitoring plots were used at Wattleridge IPA and Warra NP for several components of the research, including measurements related to fire effects, echidna activity, Backwater grevillea and dry sclerophyll forest vegetation. Stand-alone, specialised studies might have customised the layout of the monitoring plots to each component of the research differently. However, numerous constraints prevented us taking this approach. These included: time; budget; designing the research experiment around burn plans developed by the Banbai rangers, RFS and NPWS; adapting the research to take into account unforeseeable events (the Crown Mountain wildfire), and embracing the process of undertaking cross-cultural research including developing and adapting research aims and methodologies together through consultation and collaboration with Indigenous research partners. Furthermore, for the NSW component, one case study of cultural burning (and associated hazard reduction and wildfire) was documented, in one region, during one period of time. Many more studies across diverse spatial and temporal conditions are needed in order to develop a comprehensive understanding of the ecological and cultural aspects of Indigenous fire management. Therefore each of the research projects (described in Chapters 4, 5 and 7) could be considered preliminary studies with the aim to develop more specialised research over the longer term, hopefully through ongoing relationships and research programs with my Indigenous research collaborators. Other studies have similarly been generated through long-term relationships with Indigenous communities. For example, Stanley's (2019) thesis on Indigenous fire management in Cape York Peninsula was the result of 'constant conversation' and time 'out on Country' with her Indigenous research partners and their families spanning 14 years. My thesis has been developed over a 7-year relationship with the Banbai rangers and two fieldwork trips to the SEAL IPA with the Yugul Mangi rangers over 3 years. While I envy the depth and longevity of relationship that Standley has with her Indigenous collaborators, I appreciate the long-term nature of cross-cultural research and hope to continue to work with these Indigenous communities for many years into the future. Such research might result in deeper insights and more sophisticated cross-cultural methods and outcomes.

As a non-Indigenous scientist, it is important to listen, act with humility and acknowledge the people who have shared information with us. We must respect the Elders (in all cultures). Issues such as ‘white privilege’ and cultural appropriation have received heightened attention in recent times. They are considerations that I have learned to be mindful of when undertaking research, but can sometimes be overlooked due to our cultural conditioning. As a non-Indigenous scientist I cannot hope to comprehend the cosmological and cultural depth of Indigenous Australians, so my aim has been to listen and share information (where appropriate) in a cross-cultural forum. Many studies have warned of the dangers of taking Indigenous knowledge out of context or trying to assimilate it into Western knowledge systems (described in Section 1.2.4). This is why we need, first and foremost, Indigenous voices and authors, and secondly, their advocates.

8.4. Management recommendations

8.4.1. Short-beaked echidna (*Tachyglossus aculeatus*)

In Chapter 4, our cross-cultural research concluded that cultural burning at Wattleridge IPA did not significantly affect echidna activity and key habitat resources. The cultural burn was potentially beneficial for the echidna as it retained unburnt refugia and reduced fuel loads without impacting the species. This aligns with other studies that found that key habitat features are required to support echidna populations (Smith *et al.* 1989; Augee *et al.* 2006); unburnt vegetation within fire-affected areas is important as faunal refuges (Whelan *et al.* 2002; Robinson *et al.* 2013; Croft *et al.* 2016); prescribed burning may contribute to protecting refuge habitat if it avoids severe burning in a subsequent wildfire (Robinson *et al.* 2014), and fire increases the vulnerability of medium-sized mammals to predation (Hradsky *et al.* 2017).

Furthermore, the process of implementing cultural burning and monitoring the echidna allowed the Banbai rangers to fulfil some of their cultural responsibilities to look after the echidna and their Country. Therefore, it is recommended that other Indigenous communities explore renewal of the practice of cultural burning to look after ecological and cultural values, and cross-cultural monitoring could be used in other contexts to explore the impact and potential benefits of a range of land management practices.

8.4.2. Backwater grevillea (*Grevillea scortechinii* subsp. *sarmentosa*)

The Backwater grevillea has a restricted distribution, which makes it vulnerable to one-off catastrophic events, although in 2013 it was de-listed as a threatened species under the EPBC Act.

Following the Black Summer Fires of 2019–20, too-frequent fire is now a serious threat to the viability of the Backwater grevillea. Future cultural burning regimes implemented by the Banbai rangers will need to be carefully timed to avoid depleting the seed bank of the grevillea while also balancing the mitigation of wildfire risk. The data collected through this study will guide the Banbai rangers in their adaptive management of Wattleridge IPA and should inform threatened species and protected area management plans. We recommend: identifying and protecting Backwater grevillea populations as a high priority; continued cross-cultural monitoring to inform adaptive management; a re-assessment of the conservation status of the Backwater grevillea; taking a more precautionary approach to the conservation of restricted and rare species; and consideration of compounding impacts such as climate change, drought and fire, as per the *Blueprint for a conservation response to large-scale ecological disaster* in Dickman *et al.* (2020).

Specifically, we consider the following actions are urgent for the conservation of the Backwater grevillea:

- map the distribution and identify old growth/unburnt populations of the Backwater grevillea on public and private land, and prioritise for conservation activities
- adapt fire management plans to recognise the increased vulnerability of Backwater grevillea after catastrophic wildfires and to ensure that appropriate fire regimes are applied
- continue and expand (to other areas of Warra and Mann National Parks) the cross-cultural monitoring of the population and fire ecology of the Backwater grevillea, building on early work by Hunter (Hunter *et al.* 2000; Hunter 2005), our intensive study from 2014–2020 (Chapter 5), and following the catastrophic wildfires of 2019. This research would inform the adaptive management of the Backwater grevillea and also provide social, cultural and ecological benefits
- implement and expand cultural burning programs to mitigate the potential impact of wildfires
- manage threats such as weeds, feral animals and erosion through on-ground works
- consider options to establish *ex situ* (insurance) populations or commercial cultivation of the Backwater grevillea

- share our story about the Backwater grevillea to increase local community awareness and connection to this threatened species to prevent vegetation clearing on private land, and
- provide incentives for private landholders to conserve the Backwater grevillea.

8.4.3. Dry sclerophyll forest

In Chapter 7, results showed that the low and moderate severity burns did not have a significant impact on full floristics or the herbaceous layer over a 3-year period in dry sclerophyll forest on the NET in northern NSW, but that cultural burning did stimulate a mass germination event for woody seeders. This emphasises the importance of considering the fire history when comparing the impacts of various fire treatments and avoiding depletion of post-fire resources through too-frequent fire. We recommend that fire management planning and policy take into account fire history as a critical component of biodiversity conservation.

8.4.4. Fire and seasons calendars

Indigenous seasonal calendars have been used in various places around the world for monitoring and adaptive management of various resources, processes and systems (Adjaye 1987; Jiao *et al.* 2012; Woodward *et al.* 2012; Armatas *et al.* 2016; Cochran *et al.* 2016; SantoDomingo *et al.* 2016; Bhagawati *et al.* 2017; Saylor *et al.* 2017; Chisholm Hatfield *et al.* 2018; Balehegn *et al.* 2019). However, seasonal knowledge is underutilised in natural resource management (Prober *et al.* 2011) and Franco (2015) suggested ‘it is time to initiate more projects that would focus on the relevance of calendars in ecosystem management’. We used cross-cultural processes to co-develop calendars intended to guide cultural burning with the Yugul Mangi and Banbai rangers. 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. This process of co-generating knowledge, revitalising culture and caring for Country is relevant for many Indigenous communities around the world (Gavin *et al.* 2015; Johnson *et al.* 2016; Tengö *et al.* 2017; Hill *et al.* 2020b).

Our calendars have been positively received and generated interest in many Indigenous communities who also wish to develop fire and seasons calendars (McKemey and Ngoorabul Community 2018; McKemey and Wahlabul Nation 2018). The Firesticks project developed a blank template that is available for use by Indigenous communities (Firesticks Alliance Indigenous Corporation 2016). The calendars have been profiled nationally and internationally through

CSIRO's Atlas of Living Australia (Atlas of Living Australia 2016), the Australian Government's Bureau of Meteorology (Bureau of Meteorology 2016) and various media outlets (such as the Australian Broadcasting Commission and TIME magazine). In addition, the calendars are being used in primary, secondary and tertiary education institutions to foster knowledge of Indigenous culture and ecosystem management (McKemey 2020b). Within communities, the calendars are a source of pride and are used to encourage intergenerational transfer of Indigenous knowledge and use of Indigenous languages (Chapters 3 and 6). The CSIRO also developed a series of seasonal calendars from various communities across Australia, which have been widely shared and positively received (O'Connor and Prober 2010; Prober *et al.* 2011; Woodward *et al.* 2012; Prober *et al.* 2016; Bundjalung of Byron Bay Aboriginal Corporation (Arakwal) *et al.* 2019). I concur with Prober *et al.* (2011) and Franco's (2015) recommendation that Indigenous seasonal knowledge should be more widely shared and used (in culturally appropriate circumstances). There is considerable potential for the increased use of fire and seasons calendars concurrent with the revival of cultural burning and Indigenous care for Country across southeast Australia.

8.4.5. Cross-cultural knowledge and caring for Country

There is significant evidence demonstrating the social, cultural, wellbeing, environmental and economic benefits of Indigenous natural and cultural resource management (Zander and Garnett 2011; Ens *et al.* 2015; Social Ventures Australia 2016a; Jackson *et al.* 2017; Garnett *et al.* 2018; Leiper *et al.* 2018; Maclean *et al.* 2018; Zander 2018; Ansell and Evans 2019; Fa *et al.* 2020). In order to realise these benefits, increased rights and recognition for Indigenous peoples, supported with resources for long term on-ground action, are critical for conservation of biocultural diversity. Australia governments have, to some extent, enabled the recoupling of Indigenous relationships with traditional lands and sea Country and improvement in biodiversity management through the recognition of Indigenous land rights since the 1960s (Bohensky *et al.* 2013). Furthermore, Hill *et al.* (2012) found that Indigenous governance and Indigenous-driven co-governance arrangements provide better prospects for integration of Indigenous knowledge and Western science for sustainability of social–ecological systems. There is scope for increased application of these arrangements both in Australia and other parts of the world, for example, other post-colonial nation states (Thomassin *et al.* 2019).

In Australia, increased granting of land rights to Aboriginal communities over additional areas of their Country, for example through native title claims or the establishment of new IPAs, are two avenues to increase Indigenous people's ability to care for their Country. Other opportunities

include: more participation of Indigenous peoples through co-management agreements of protected areas; roles on privately owned conservation land; increased access to public land such as Crown land or Travelling Stock Routes; and increased engagement with private landholders, many of whom are seeking partnerships with Indigenous groups to manage their land.

8.4.6. Cultural burning

The 2020 Bushfires Royal Commission report (Binskin *et al.* 2020) highlighted the importance of cross-cultural knowledge for fire management and recommended that Australian, state, territory and local governments should ‘engage further with Traditional Owners to explore the relationship between Indigenous land and fire management and natural disaster resilience’ (Recommendation 18.1) and ‘explore further opportunities to leverage Indigenous land and fire management insights, in the development, planning and execution of public land management activities’ (Recommendation 18.2). The 2020 NSW Bushfire Inquiry final report (Owens and O’Kane 2020) made two recommendations (Recommendations 25 and 26) regarding Indigenous cultural burning, the most pertinent being ‘Government commit to pursuing greater application of Aboriginal land management, including cultural burning, through a program ... working in partnership with Aboriginal communities. This should be accompanied by a program of evaluation alongside the scaled-up application of these techniques.’ This thesis describes the process of reintroducing and evaluating cultural burning, as recommended in these two landmark reports, which could become far more widespread – and illustrates a process that many other communities may soon embark upon, providing outsiders (such as government decision makers) with an insight into what happens on the ground and how knowledge is shared (within and between cultures) for cultural burning. Our study is one example of the development of cultural fire management, how people are learning to apply cultural burning, and the information they use to make decisions. Additionally, our research demonstrates the importance of everyone working together in contemporary circumstances to co-produce knowledge to guide cultural fire management. I hope that the research in this thesis helps people to visualise what cultural burning can look like if it is adopted by other communities at a broader scale, for example, as proposed by the Firesticks Alliance Indigenous Corporation (Costello and Standley 2020).

8.5. Future research

The next steps in the research embarked on here should focus on supporting Indigenous research priorities and methodologies (outlined in Section 8.3). Where there is complementarity between

Indigenous and non-Indigenous research priorities, these should be pursued. Some of the assumptions related to Indigenous fire management also need to be challenged through research, for example, that Indigenous knowledge and practice of cultural fire management has been ‘lost’ in southeast Australia, that Indigenous culture is a traditional, static entity that cannot adapt to changed circumstances, that skills and knowledge related to cultural fire management are not transferable from north to south Australia, and that cultural burning does not effectively reduce fuel loads. The scientific method has been used in this thesis to evaluate these claims and evidence has been obtained that challenges some of these assumptions. However, additional evidence and more studies are needed in order to evaluate these assumptions in the scientific and broader community more thoroughly.

In view of the multiple ‘wicked problems’ associated with the Pyrocene, such as ongoing ecosystem degradation and climate change (Prober *et al.* 2019) and the need for Australian society to continue the journey of reconciliation with its First Nations peoples, further research into using cross-cultural approaches, managing fire and adapting to climate change should be a high priority. In the short term, the impact of the Crown Mountain wildfire at Wattleridge IPA and Warra NP provides a unique opportunity to compare the outcomes of cultural burning and hazard reduction burning, with a wildfire. While we have already done this for the Backwater grevillea, it will be worthwhile to extend this research to the whole of the dry sclerophyll forest community and associated fauna generally.

8.6. Conclusion

Australia has a history of at least 65,000 years of Indigenous people living on, with, and in a deeply intimate relationship with Country. In the last 232 years colonisation brought with it frontier warfare, massacres, slavery and systemic and institutional cultural genocide (Macpherson 1860; Clayton-Dixon 2019). Colonisers were not willing to share the land with Indigenous people (McBryde 1978; Sonter 2018), and dispossession of land occurred in most parts of southeast Australia, with the exception of reserves, missions and land of little value to the colonisers. The marginalisation of Indigenous people and destruction of the Indigenous cultural landscape continues today (Stanley and Gudgeon 2020), with limited improvement in Indigenous health, and social and economic disadvantage (The Lowitja Institute 2020). The Australian Government funds programs such as the Indigenous Protected Areas and Working on Country (Murphy 2016; Davidson 2017), albeit disproportionately and inadequately (Preece 2019; Strelein *et al.* 2020). The responses and actions of democratically elected Australian governments are too slow and too little

on issues of fundamental importance, such as constitutional and legislative support as well as truth-telling through the *Uluru Statement from the Heart* (The Uluru Statement 2020). In 2020, the world focused attention on issues of global impact such as #blacklivesmatter and the Australian bushfires. In the heart of all Australians, ‘making room and moving over’ (Latulippe and Klenk 2020) to allow for justice, healing and self-determination for First Nations people, is a matter of simple decency. We must recognise the injustices of our past, acknowledge that their legacy continues today, and actively work together to successively decolonise our country (Neale *et al.* 2019a).

One of the most effective ways to do this is to support Indigenous people to work on Country. The multiple benefits of this have been demonstrated repeatedly (Social Ventures Australia 2016a), including in this thesis. Reintroducing cultural fire management is one step in this process which could help to address many of the problems facing Australia. Non-Indigenous people cannot stand back and let Indigenous people do all the work. These are fundamental human rights issues (Australian Human Rights Commission 2020) that everyone must work to solve together. Non-Indigenous Australians must be allies and advocates for their First Nations partners. Scientists, policy makers and practitioners all have the opportunity to support and engage with local Indigenous custodians. We must take these opportunities and use them to heal our country, with its sad and terrible history, its damaged ecosystems (Kearney *et al.* 2019) and a deeply concerning future looming (Pyne 2019; Bureau of Meteorology and CSIRO 2020).

Restoration and reparation of land and relationships is a slow and painful process, but it can change lives and bring joy to people on both sides of the cultural divide. Through this thesis we have provided a glimpse of how this has happened for the Banbai people and their allies. Top-down policy, legislation, support and resources, coupled with bottom-up local engagement, support and initiatives are needed to increase Indigenous opportunities to care for their Country. The cultural burning revival in southeast Australia illustrates some of the dynamics of these processes, driven by grass-roots Indigenous-led movements with corresponding policy development by state authorities. The ongoing rollout of cultural burning, particularly in response to state and federal bushfire inquiries in 2020, will continue to provide insight into the race relations unfolding in Australia, and a litmus test for the willingness of settler governments to devolve power and embrace the wisdom and practicality of a culture that has survived in this country for at least 65,000 years, or as Indigenous people put it, ‘forever’.

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Appendices

Appendix 2.1

Themes and subthemes coded from media and academic literature:

- Background to Indigenous burning
- Indigenous burning is better
- Reintroduction / revival cultural fire management
- Describes cultural fire management
- Multi agency involvement / collaboration
- Risk of bushfire
- Our relationship with fire
- Respect between Indigenous & non-Indigenous people
- Two-way / working together
- Aboriginal rights
- Indigenous leadership in fire management
- Funding
- Training
- Lack of recognition of Indigenous knowledge
- Identifies research gap
- Recommends more research
- Impacts of colonisation on cultural fire management
- Cultural burning (CB) benefits:
 - o General benefit
 - o Social benefit
 - o Cultural benefit
 - o Environmental benefit
 - o Bushfire management benefit
- Examples of Indigenous burning
- Destruction caused by bushfires (BF Destruction):
 - o Homes
 - o Lives
 - o Infrastructure
 - o Cultural
 - o Wildlife / vegetation
 - o Livestock
 - o Trauma /grief
 - o General
- Blame (BLAME) for bushfires:
 - o Conservationists / greenies
 - o Climate change
 - o Politicians
 - o Arson
 - o Fuel loads

- Permits/ red tape
 - Lightning /weather
 - Mismanagement
 - Other
- Impediments (IMPED) to bushfire management:
 - Urbanisation
 - Infrastructure
 - Boundaries
 - Resourcing
 - Power
 - Training
 - Lack of recognition
- Strategies (STRATEGY) for bushfire management:
 - Hazard reduction
 - Cultural burning
 - Fire fighting
 - Fire proof buildings
 - Green fire breaks
- Cultural aspects of Country
- Cultural burning protected something
- Decolonisation

Appendix 2.2

Case studies of contemporary cultural fire management in southeast Australia identified in the literature

Place	People	Land Tenure Type	Land area (ha)	Description	Reference
NSW					
Rick Farley Reserve, far south-western NSW.	Mothers Ancestral Guardians Indigenous Corporation; Barkindji, Mutthi Mutthi and Ngyiampaa people; NSW Government staff; local schools; local land-holders; general public	Crown land and western lands lease. Aboriginal land.	300 ha	Land management at Rick Farley Reserve for restoring Malleefowl habitat using an Aboriginal cultural framework (which includes cultural burning). The aim is to also bring culture back to that landscape. The program has been supported by the Environmental trust, Local Land Services; Department of Education; National Malleefowl Recovery Team. Program is on-going.	Booth (2020)
Yellomundee Regional Park (Shaws Creek Aboriginal Place) NSW	Darug Aboriginal community, NPWS, Greater Sydney Local Land Services, Koori Country Firesticks Aboriginal Corporation, Firesticks Alliance, GBWHI Blue Mountains World Heritage Institute, various universities.	Public lands (dedicated Aboriginal place within NSW National Parks)	485 ha	Multiple Aboriginal Cultural Burns and camp held in Yellomundee Regional Park. Project aims: Aboriginal cultural engagement and knowledge sharing, weed control, habitat restoration.	Darug Ngurra <i>et al.</i> (2019); McGrath (2019); Environment Energy and Science Group (2020)
Hunter Valley, NSW	9 LALCs and TO groups, Firesticks Alliance Hunter LLS	Public & Aboriginal (LALC) lands	>100 ha	The Cultural Burn Mentoring Program will run over the next three years, in partnership with nine Local Aboriginal Land Councils and Traditional Owner groups, Firesticks Alliance Indigenous Corporation and Tocal College. The program is supported through funding from the Australian Government's National Landcare Program, NSW Government's Catchment Action NSW and Department of Education and Training. The program will initially see 22 Aboriginal students complete Conservation and Land Management training, where for the first time cultural burning practices have been	Bush (2019); Environment Energy and Science Group (2020)

				included as key modules of the training program. Several sites were selected on both public and LALC lands for the initial training, with some cultural burns conducted, and post burning these will be monitored over coming years, and applied with additional burning as needed. Additional sites in the lower Hunter will be included in the program in coming weeks.	
South Coast -Bega Valley	Firesticks Alliance with Indigenous Corporation (Southern Yuin Firesticks)	State forest flora reserve (managed by NPWS)	11,811 ha	<i>Burning for Healthy Country – Not Hectares</i> . Aims include: habitat and threatened species protection, Aboriginal cultural engagement and knowledge sharing, reducing fuel loads.	Department of Planning Industry and Environment (2020a)
Bega Valley, Tathra	Bega LALC Firesticks Alliance	Private land (owned by Bega LALC)		The Bega Local Aboriginal Land Council is the largest private landholder in the Bega Valley, responsible for the management of a vast area of bushland, much of which is on urban fringes. Aboriginal work crews have learnt from Victor Steffensen and other Aboriginal cultural fire practitioners from the Firesticks Alliance community of practice as well as training with the Rural Fire Service. Cultural burning practitioners also work with farmers and other private landowners on using traditional methods as part of their farm and environmental management.	Brown (2020)
Tweed Shire Council area	Madhima Gulgan Community Association	Five different land tenures	Unconfirmed	Cultural burning workshops and practices as part of bush regeneration practices.	Sleeman (2018)
Bundanon Trust	Yuin Country Mudjingaalbaraga Firesticks, Firesticks Alliance, South East LLS	Trust land (total area 1,100ha)	150ha burnt during National Indigenous Fire Workshop 2018	Cultural burning as part of caring for landscape, using Bundanon as a place for research and experiment and fulfilling obligations towards local Aboriginal community.	Maclean <i>et al.</i> (2018); Taylor (2018)
Five Ways Travelling Stock Route near Henty NSW (Riverina)	Wiradjuri	Public (Travelling Stock Route)	?	Cultural burning on TSR	NSW Rural Fire Service (2017)
Mulgoa	Darug Country Coordinated by Koori Country Firesticks Aboriginal Corporation,	Site managed by Cumberland Land Conservancy	?	2 day cultural burning workshop	McGrath (2017)

	Firesticks Initiative, Mulong Arts				
NCC Firesticks Project	Northern Rivers and New England Tablelands regions of NSW, including four Indigenous Protected Areas (listed below) and three Local Aboriginal Land Council (LALC) properties	Aboriginal and other land	Fire planning completed for 23,380ha	This project empowered Aboriginal communities to implement fire management programs across 6,680ha of IPA and Aboriginal land and 16,700ha of regionally significant corridors.	Tamarind Planning (2017)
Minyumai IPA	Bandjalang Clan of the Bundjalung Nation	Aboriginal land	Fire planning completed for 2,100 ha as per NCC Firesticks Project	Cultural burning program across IPA.	Kerr (2019)
Ngunya Jargoona IPA	Jali Local Aboriginal Land Council, Nyangbul Clan of the Bundjalung Nation	Aboriginal land	Fire planning completed for 1,114 ha as per NCC Firesticks Project	Cultural burning program across IPA.	Kerr (2019)
The Willows-Boorabee IPA	Glen Innes Local Aboriginal Land Council, Boorabee Aboriginal Corporation	Aboriginal land	Fire planning completed for 2,900 ha as per NCC Firesticks Project	Cultural burning program across IPA.	Holmes <i>et al.</i> (2009); McKemey and Ngoorabul Community (2018); Kerr (2019); McKemey <i>et al.</i> (2019a)
Wattleridge IPA Tarriwa Kurrukun IPA	Banbai Land Enterprises Incorporated with support from Tamworth Local Aboriginal Land Council	Aboriginal land	Fire planning completed for 480 ha as per NCC Firesticks Project 8 ha burning implemented	Cultural burning program across IPA. Mentoring other Aboriginal groups on cultural burning. Cross-cultural research on process and outcomes of cultural burning. Banbai rangers funded by the Commonwealth Government Working on Country Program.	Maclean <i>et al.</i> (2018); McKemey and Patterson (2018); Kerr (2019); McKemey and Patterson (2019); McKemey <i>et al.</i> (2019b); McKemey and Banbai Nation (2020)
Dorrobbee Grass Reserve, northern NSW	Widjabul/Wiyabul of the broader Bundjalung peoples Ngulingah Aboriginal Land Council Working on Country team	Public Land (Trust) and Aboriginal land	12 ha burn area	<i>Grassy Cultural Pathways at Dorrobbee Grasslands Reserve</i> . Cultural burning annually. Project aims: Aboriginal cultural engagement and knowledge sharing, threatened species protection, hazard reduction.	Kerr (2019) Environment Energy and Science Group (2020)
Nimbin Rocks and land around Lismore	Ngulingah Aboriginal Land Council Working on Country team	Aboriginal land	?	Cultural Burn planning for cultural values, threatened species protection, hazard reduction and weed control.	Kerr (2019)
Dobie's Bight and Busby's Flat	Casino Boolangle Land Council	Aboriginal land	112 ha	Cultural Burn planning for cultural values, threatened species protection, hazard reduction and weed control.	Kerr (2019)

Helmet range	Gugin Gudduba Land Council	Aboriginal land	?	Cultural Burn planning for cultural values, threatened species protection, hazard reduction and weed control.	Kerr (2019)
Coastal Themeda Headlands, Coffs Harbour	Gumbaynggirr	Public land (NPWS)	?	Protect Aboriginal cultural values; grassland restoration; threatened species protection.	Kerr (2019)
Dorrigo / New England escarpment	Gumbaynggirr and others	Public land (NPWS)	50 ha	Restoring 'Grassy Island' Bio-cultural Landscapes along the Dorrigo/ New England Escarpment. Project aims: protect Aboriginal cultural values; grassland restoration; threatened species protection.	Kerr (2019) Environment Energy and Science Group (2020)
Muli Muli/Woodenbong area	Githabul rangers	Public land (State Forest)	?	Tackling lantana and bell miner dieback	Kerr (2019)
Jubullum	Jubullum Local Aboriginal Land Council	Aboriginal land	10 ha	'Cultural Fire Gatherings – Making our way together', a series of local on-Country workshops held at Jubullum Local Aboriginal Land Council and facilitated by Firesticks Alliance in partnership with the Northern Tablelands Local Land Service, Banbai rangers and Jagun Alliance. The aim of the gathering was to "bring together current and aspirational fire projects and consider a regional approach to cultural fire management in north-eastern NSW"	Maclean <i>et al.</i> (2018); McKemey and Wahlabul Nation (2018); Kerr (2019)
Monaro Plains	Rod Mason	Private land	?	Landcare field day to learn about cultural burning	Brown (2016b)
Monaro Plains	Aileen Blackburn, Ngarigo traditional custodian	Public land (Travelling Stock Routes)	?	Trials of traditional burning for recovery after Manna gum dieback	Brown (2016a)
Arakwal National Park, Byron Bay	Arakwal/Bundjalung	Public	<10 ha	Joint management of Arakwal National Park, including cultural burning.	CSIRO <i>et al.</i> (2019)
Mid-north coast	Many Aboriginal groups	To be confirmed	To be confirmed	NSW Koala Strategy: Conservation through community action - Learn from Aboriginal communities on protecting koala habitat. Project aims: Aboriginal cultural engagement and knowledge sharing, capacity building, threatened species protection, collaboration and knowledge sharing.	Environment Energy and Science Group (2020)
Cumberland Plain	Darug	National park, council and private land	< 6400 ha (7 sites of unknown size)	<i>Cumberland Plain Restoration Program – Saving the Cumberland Plain Woodland with fire.</i> Project focus: restoration of endangered ecological community,	Environment Energy and Science Group (2020)

				Aboriginal cultural engagement and knowledge sharing, habitat restoration.	
South coast- Nowra	Yuin	National park	3.5 ha	<i>Tripalina Reserve Cultural Burn Project</i> . Project focus: threatened species protection, hazard reduction, and weed control. New project to commence in 2020 called <i>Djamaga ganji (Good Fire)</i>	Environment Energy and Science Group (2020)
South Coast - Eurobodalla	Batemans Bay Local Aboriginal Land Council	Aboriginal land	>50 ha	<i>Cultural Land Management – Protecting Threatened Flora & Fauna</i> . Project focus: habitat restoration, Aboriginal cultural engagement and knowledge sharing, threatened species protection, pest management.	Environment Energy and Science Group (2020)
North Coast - Lismore	Jagun Alliance Aboriginal Corporation	Aboriginal land	>50 ha	<i>Good Fire on Helmet Grassy Habitats</i> . Project focus: threatened species protection, habitat restoration, weed management.	Environment Energy and Science Group (2020)
South Coast - Eurobodulla	Mogo Local Aboriginal Land Council	Aboriginal land	>10 ha	<i>Grandfathers Gully Land Regeneration and Midden Protection</i> . Project focus: restoration of cultural site, threatened species protection, habitat restoration.	Environment Energy and Science Group (2020)
South West -Griffith	Griffith Local Aboriginal Land Council	Aboriginal land	>10 ha	<i>Mallison Road Restoration and Rehabilitation Project</i> . Project focus: regeneration, weed management, Aboriginal cultural engagement and knowledge sharing, capacity building.	Environment Energy and Science Group (2020)
South East - Yass Valley	Onerwal Local Aboriginal Land Corporation	Aboriginal land	>5 ha	<i>Onerwal LALC Cultural Fire Practices</i> . Project focus: Aboriginal cultural engagement and knowledge sharing, habitat restoration.	Environment Energy and Science Group (2020)
North Coast - Dorrig NP and Gaagal Wanggaan (South Beach) NP	Gumbaynggirr Community	National park	?	<i>Gumbaynggirr Community Cultural Burn Capacity Development Project</i> . Project focus: Aboriginal cultural engagement and knowledge sharing, threatened species protection, capacity building.	Environment Energy and Science Group (2020)
Mangrove Mountain, Central Coast	Darkinjung Local Aboriginal Land Council	Public land	?	<i>Darkinjung Mirring Women Muree (the fire spirit) Warre Warren Project</i> . The project will train Aboriginal people (mostly women) in conservation and land management practices through such activities as the use of cultural burning and traditional knowledge sharing between	Environment Energy and Science Group (2020)

				Aboriginal Elders, youth and the community.	
Batemans Bay region	Batemans Bay Local Aboriginal Land Council	?	?	<i>Cultural Land Management</i> – Protecting Threatened Flora & Fauna. The project seeks to protect threatened and vulnerable species and target feral animals under the development of a Land Management Plan. The project will improve habitats through cultural burns, rehabilitating degraded land preventing further loss of habitat and protect the environmental flora and fauna by re-establishing lost traditional practices using fire to heal the Country, with proper fire management as an essential part of this process.	Environment Energy and Science Group (2020)
Tathra	Firestick Alliance Indigenous Corporation (facilitated by Southern Yuin)	Public land (State Forest managed by NPWS)	?	<i>Burning For Healthy Country - Not Hectares</i> . This project is to develop a long-term Cultural Burning Program within the Southern Yuin Nation that supports Cultural Burning practice to take place within threatened species habitats and connect community back to Country. The project will enable Cultural Burning Crews and Traditional Owners to work together alongside NSW National Parks and Wildlife Service (NPWS) and Rural Fire Service (RFS) staff within the Murrah Flora Reserve, to improve the health of the local area by protecting, enhancing and supporting threatened species habitats, such as a significant koala population, the long-nosed potoroo, the yellow-bellied glider and the powerful owl, while reducing fuel loads. The project will seek to reduce extreme fuel loads by providing an alternative approach to current Hazard Reduction block burning methods.	Environment Energy and Science Group (2020)

Place	People	Land Tenure Type	Land area (ha)	Description	Reference
VIC					
Teesdale	Wadawurrung Traditional owners, Wathaurong Aboriginal Cooperative, Aboriginal community	Aboriginal land	?	2 burns at Wurdi Youang & Bakers Lane Reserve Wiyn-Murrup Yangarramela (Fire Spirit Comes Back). Joint Fire Project co-ordinated through the Corangamite Catchment Management Authority, Victoria. This project was developed via a collaborative partnership between the Wathaurong Aboriginal Corporation, the Country Fire Authority (CFA), the Department of Environment, Land, Water & Planning (DELWP), Glenelg Hopkins Catchment Management Authority (GHCMA), Golden Plains Shire Council (GPSC) and Parks Victoria (PV). The stated aim of the multi-partner project was “to assist Wadawurrung people and Aboriginal community of western Victoria to meet their expressed aspirations to practice traditional burning for the health of Country and People”.	Corangamite CMA (2017); Maclean <i>et al.</i> (2018)
Central western Vic (Bendigo)	Dja Dja Wurrung	Public lands	Size varies from 8 – 153ha per burn	8 fires implemented, 22 more planned on public lands. Agreement between Dja Dja Wurrung Clans Aboriginal Corporation Department of Environment, Land, Water and Planning (DELWP) and Parks Victoria (PV). ‘These burns are believed to be among the first Aboriginal-led traditional burns on public lands in southeast Australia since the settler invasion began more than 180 years ago.’	Neale <i>et al.</i> (2019a) Wales (2019)
Whipstick - Djandak Wi - Bright’s Lane	Dja Dja Wurrung people through Dja Dja Wurrung Clans Aboriginal Corporation	Public land, partnership with DELWP	20	This was the first burn in the Djandak Wi program conducted in partnership by Dja Dja Wurrung CAC, DELWP, Parks Vic	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Maryborough - Djandak Wi - Happy Tommy	Dja Dja Wurrung people through Dja Dja Wurrung Clans Aboriginal Corporation	Public land, partnership with DELWP	26.2	Djandak Wi	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)

Nardoo Hills Reserves	Dja Dja Wurrung people through Dja Dja Wurrung Clans Aboriginal Corporation	Private Conservation Area, partnership with Bush Heritage (NGO)	30	Private burn supported by Bush Heritage and Barapa Land and Water	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Budgerum	Barapa Barapa	Barapa Land & Water	?	Private burn, supported by Dja Dja Wurrung	Webster (2020)
Boort - Little Lake Boort	Dja Dja Wurrung people through Dja Dja Wurrung Clans Aboriginal Corporation	Public land, partnership with DELWP	2.83	Djandak Wi, supported by Barapa Land and Water	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Yerrip - Rock Crossing	Dja Dja Wurrung people through Dja Dja Wurrung Clans Aboriginal Corporation	Public land, partnership with DELWP	1?	Djandak Wi	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Yerrip - Avonmore Bridge	Dja Dja Wurrung people through Dja Dja Wurrung Clans Aboriginal Corporation	Public land, partnership with DELWP	8?	Djandak Wi	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Cohuna - Barapa Iron Punt Track	Barapa Barapa, through Barapa Land and Water	Public land, partnership with DELWP	?	Supported by Barapa Land and Water	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Ngarri - Mt Egbert	Dja Dja Wurrung people through Dja Dja Wurrung Clans Aboriginal Corporation	Public land, partnership with DELWP	7.78	Djandak Wi	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Dyurrit (Mt Arapiles) Walpa /Wanjap (Burn / Fire)	Wotjobaluk, through Barengi Gadjin Land Council + Wotjobaluk elders	Public land, partnership with Parks Vic	Target area 8ha total with small burns 0.1 – 1 ha each	Provides an opportunity for Traditional Owners to have access to Country where caring for our Country has been absent for a long time. Traditional owners wish to look after Country as their ancestors did for thousands of year and to practice fire techniques in hopes to build capacity and skills on how to read and understand county using fire as the tool. The site is long unburnt with a lot of non-native grasses being the dominant species. Working on a rotation to burn sections at a time to create different age class and mosaic effects across this important Country	Forest Fire Management Victoria and Country Fire Authority (2020); Skurrie (2020); Neale (pers. comm.)

Barapa Barapa - Flannery NCR Rowlands	Barapa Barapa, through Dja Dja Wurrung CAC and Barapa Land and Water	Public land, partnership with Forest Fire Management/DELWP	200	Supported by Barapa Land and Water	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Woolshed Swamp Boort	Dja Dja Wurrung people through Dja Dja Wurrung Clans Aboriginal Corporation	Public land, partnership with Forest Fire Management/DELWP	12.39	Djandak Wi, supported by Barapa Land and Water	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Arapiles - Walpa Dyurrita	Wotjobaluk, through Barengi Gadjin Land Council + Wotjobaluk Elders	Public land, partnership with Forest Fire Management/DELWP	9		Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Tang Tang Swamp	Dja Dja Wurrung people through Dja Dja Wurrung Clans Aboriginal Corporation	Public land, partnership with Forest Fire Management/DELWP	21.27	Djandak Wi, supported by Barapa Land and Water	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Skipton - Mt Emu Creek	Gunditjmara	Private, in partnership with CFA	?	Cultural burn on the old Mission reserve	Forest Fire Management Victoria and Country Fire Authority (2020); Neale (pers. comm.)
Euroa	Not provided	Private land	?	Euroa Arboretum and the Country Fire Authority supporting Aboriginal cultural fire management on private properties in north east Victoria	Maclean <i>et al.</i> (2018)
ACT					
ACT	Ngunnawal	Public lands	?	An ACT government 'cultural burning' program was developed after being suggested by then Senior Aboriginal ranger, Ngunnawal man Adrian Brown, and supported by managers for its risk mitigation potential as well as being 'the right thing to do'. These cultural burns are listed within the ACT's annual bushfire operational plan alongside 'hazard reduction' and 'ecological' burns. The cultural burns are undertaken on public lands by staff from the ACT Parks and Conservation Service, who are predominantly Aboriginal people from other parts of Australia. Ideally, the traditional custodians identify the priority burn areas and a traditional Ween Bidja (fire boss) lights the fire.	Weir <i>et al.</i> (2020)

Jerrabomberra Wetlands	Murrumbung rangers	Public land (parks)	8.7ha	At Jerrabomberra Wetlands in Fyshwick, Canberra, Wiradjuri man and ACT Parks and Conservation Service, Aboriginal Fire Management Officer, Dean Freeman, oversaw the final scheduled cultural burn for the 2019 calendar year. Like all cultural burns in the ACT, it was planned and managed by a collective of Indigenous people working for ACT Parks known as the Murrumbung rangers and was lit by a local Ngunnawal elder.	O'Mallon (2018); Guest Author (2019)
SA					
Adelaide	Kurna people in partnership with City of Adelaide	Public land	?	Trial cultural burn within the City of Adelaide. Council plans to trial and possibly adopt this practice in Autumn 2020 at Mirnu Wirra (aka Golden Wattle / Park 21W), in a western section of the Adelaide Park Lands.	Stewart (2020)
TAS					
truwana/ Cape Barren Island	Truwana rangers, supported by Aboriginal Land Council of Tasmania	Aboriginal land	?	Fire management project, partnership between Truwana rangers and Tasmania Fire Service. Federal Government Indigenous Advancement Strategy and Working on Country program.	Whiting (2017); Maclean <i>et al.</i> (2018)
Ross	Tasmanian Aboriginal Centre	Private land	?	Cultural burning through partnership with private landholders, University of Tasmania, NGOs	McIntyre (2018)
lungtalanana/ Clark Island	Tasmanian Aboriginal Centre	Aboriginal land	?	Land management program run by Tasmanian Aboriginal Centre	Maclean <i>et al.</i> (2018)
Tasmanian Wilderness World Heritage Area	Palawa, Tasmanian Aboriginal Land Council	Public land	?	Attempt to reintroduce cultural burning in 2000	Lehman (2001)
Tasmania including: - Big Dog Island mutton bird rookery – Bass strait Islands - Preminghana IPA – North west Tasmania - Putalina IPA – Southern Tasmania - Piyura kitina IPA – Southern Tasmania - Cape Barren Island- Bass strait Islands	Tasmanian Aboriginal Centre (TAC) and the Aboriginal Land Council of Tasmania	Aboriginal and private lands	The total combined land area of these areas is over 60,000ha	Tasmania Cultural Fire Mentoring Program 2014 – 2023: Fire projects on Aboriginal lands are now in the fifth year of practice and are undertaken on 8 IPA properties owned and managed by the Aboriginal community.	Costello and Standley (2020)

- Trawtha Makuminya Aboriginal Land- Central Highlands - Chapel Island IPA – Bass Strait Islands - Lungtalanana IPA – Bass Strait Islands - Kings Run Aboriginal Land- North West Tasmania					
QLD					
Bunya Mountains	Bunya Mountains Murri rangers of the Bunya People's Aboriginal Corporation	Public land (mostly Russell Park, a conservation reserve in the Bunya Mountains on Western Downs Regional Council managed lands)	?	The purpose of the Murri rangers' fire management is to protect and maintain the culturally significant Bunya Balds grasslands, heal the Country and its people, develop networks and partnerships. Supported through Burnett Mary Regional Group.	Maclean <i>et al.</i> (2018); Kerr (2019)
Sunshine Coast	Kabi Kabi people, Bunya Bunya Country Aboriginal Corporation	Private land	?	Cultural burning on private land in partnership with large development company (Stockland)	Cannan (2020)
Warwick	?	Private land?	?	Place-based cultural fire workshops, such as the 'Burning for healthy land' workshop hosted by the Condamine Headwaters Landcare group southeast Queensland, supported by the Condamine Alliance through funding from the National Landcare Program. This workshop brought together Indigenous farmers from the Warwick region with the Bunya Mountain Murri rangers and Victor Steffensen to "present innovative and challenging ideas for managing land, which make a lot of sense to many local landholders and farmers"	Maclean <i>et al.</i> (2018)

Appendix 3.1

Semi-structured interview questions SEAL IPA

Field work June 2016:

What are the seasons here?

When is the hot/cold time?

What is the weather like?

What bush tucker do you eat?

When do you eat it?

Do any plants or animals tell you when the seasons are changing or that animals are ready to eat?

When do you burn?

When should you not burn?

How do you know if it is the right time to burn?

Who does the burning?

How is the burning going?

Do you go out burning?

How did you learn how to burn?

How did the old people burn?

Why did the old people burn?

Why do you burn today?

How do you burn now?

How is burning different today to in the past?

When you go out burning how does it make you feel?

Do kids learn about burning?

Can you tell me about carbon farming/savanna burning?

Field work June 2019:

Is the information in the Fire & Seasons calendar correct?

Are you happy to have your quote/photo/information used in the calendar, paper and thesis publications?

How is burning in SEAL IPA going?

How is SEALFA progressing?

What have you learned/experienced in the first three years of SEALFA?

What benefits have you seen from SEALFA?

How does SEALFA affect:

Resources for rangers and the community?

The relationship between rangers and Traditional Owners?

What are the issues that are causing tension?

Are you able to undertake traditional fire management as part of SEALFA?

Were you able to undertake traditional fire management before SEALFA?

Do Traditional Owners go out burning with rangers?

Do you think this calendar will help? How?

How will you use this calendar?

How can we improve the draft calendar?

What things need to be done to improve fire management overall?

Appendix 4.1

Semi-structured interview questions regarding echidna and cultural burning at Wattleridge IPA

Please tell me your name and role here at Wattleridge IPA?

What fire management practices do you use and how did you learn them?

Are you able to use traditional Aboriginal burning techniques? If not, why not?

How can fire be used to manage culturally important animals and plants?

Why is the echidna important to you?

What did you observe when we were monitoring the echidna?

What have you noticed since?

What do these results mean to you?

How do you think fire affected the echidna?

Do you think we should burn more or less for the echidna?

What type of burning is best for the echidna? No burning, low intensity burning or moderate intensity burning?

How will you use these results when you are managing the IPA?

Would you like to continue to monitor important animals and plants in this way?

What do you think we could have done better?

Would you like to do more or less work like this? Why?

What other plants, animals and management practices would you like to monitor?

Have you learned anything from this monitoring? If so, what?

On a scale of 1 to 10, how much would you say you have learned?

Do you think you could continue to do this monitoring yourself?

Appendix 5.1

Semi-structured interview questions regarding Backwater grevillea at Wattleridge IPA

Please tell me your name and role here?

What were we doing here today?

Why did we do it?

How did we do it?

Why is the Backwater grevillea important to you?

Does the grevillea have any traditional significance to the Banbai people?

Do you have any stories or interesting facts about the Backwater grevillea to share?

What did you observe when we were monitoring the Backwater grevillea?

How do you think fire affected the Backwater grevillea?

Do you think the plants that came back after the fire are mostly seedlings or suckers?

Why is this important?

Do you think the population of the Backwater grevillea is healthy here at Wattleridge?

Why do you think that?

What are some of the threats to the Backwater grevillea?

Are you doing any management to reduce those threats? What actions are you taking?

What do these results mean to you?

Do you think we should burn more or less for the Backwater grevillea?

What type of burning is best for the Backwater grevillea? No burning, low-intensity burning or moderate-intensity burning?

Why is that type of burning better?

How will you manage fire on Wattleridge from now on?

How will you use these results when you are managing the IPA?

Would you like to continue to monitor important animals and plants in this way?

What do you think we could have done better?

Would you like to do more or less work like this? Why?

What other plants, animals and management practices would you like to monitor?

Have you learned anything from this monitoring? If so, what?

On a scale of 1 to 10, how much would you say you have learned?

Do you think you could continue to do this monitoring yourself?

How do you think Crown Mountain fire affected the black grevillea?

Have fuel loads increased or decreased after the bushfire?

What are you going to do to manage the grevillea going forward?

Do you think the fire affected the reproduction of the black grevillea?

Do you want to keep doing the cultural burning?

If you are able to protect the grevillea, how would that make you feel?

Appendix 6.1

Semi-structured interview questions regarding *Winba = Fire*

Initial questions during fieldwork on Country, pre-fire:

Why is the Country we see here important?

Are there any cultural stories, sites, values and bush foods or resources here that you would like to talk about?

Are there any plants here that you expect to change with fire and what changes do you expect?

Are there any plants that change during the year that indicate that the seasons are changing or that it is a good time to collect certain bush tucker or that it is a good/bad time to burn?

Are there any animals that change during the year that indicate that the seasons are changing or that it is a good time to collect certain bush tucker or that it is a good/bad time to burn?

What seasons do you recognise?

What are these seasons called?

How do you describe these seasons?

How does the weather change? E.g. rain, wind, temperature etc.

How do you know when to burn your Country?

Looking at this seasonal calendar template, how would you fill it in?

Ongoing collaborative fieldwork on Country, pre and post-fire:

What plants have you noticed fruiting or flowering this month?

What animals have you observed this month?

What weather conditions have you observed this month?

What changes have you noticed since the fire?

What plants are regenerating after the fire?

What animals have you observed since the fire?

Is this month a good time to burn? Why? Why not?

Following calendar development:

What information do you use to manage fire at Wattleridge?

Why did you develop this calendar?

How will you use it?

Is it important to you? Why?

What knowledge did you use to develop the calendar?

What process did you go through to develop the calendar?

What are different components of the calendar?

Can you tell me about the Banbai language? Will this help the language to continue?

Why is it important to teach kids language?

Can you tell me about some of the biocultural indicators used in the calendar?

How will this calendar help you to manage fire at Wattleridge? And general NRM?

On a scale of 1 to 10 how much has this calendar improved your knowledge in general?

On a scale of 1 to 10 how much has this calendar improved your knowledge of fire management?

How has the calendar been used in the local community?

How has it been used in the wider community?

What information do we need to continue to add as the years go by?

What are some of the knowledge gaps that we need to fill?

Would you like there to be more research like this? If so, what?

Is there anything else you would like to say?

Appendix 6.2

Scientific names (sources include (Cubis 1977; Zola and Gott 1992; Hunter 2003b; McKemey and White 2011; Milledge 2017). Nomenclature follows that of PlantNET (<http://plantnet.rbgsyd.nsw.gov.au/> sourced July 2020).

Animals	
Common name	Scientific name
Amphibians	
Common Eastern Froglet	<i>Crinia signifera</i>
Eastern Banjo Frog	<i>Limnodynastes dumerilii</i>
New England Tree Frog	<i>Litoria subglandulosa</i>
Peron's Tree Frog	<i>Litoria peronii</i>
Spotted Grass Frog	<i>Limnodynastes tasmaniensis</i>
Whistling Tree Frog	<i>Litoria verreauxii</i>
Reptiles	
Macquarie Turtle	<i>Emydura macquarii</i>
Bearded Dragon	<i>Pogona barbata</i>
Eastern Water Dragon	<i>Intellagama lesueurii</i>
Highland copperhead	<i>Austrelaps ramsayi</i>
Red-bellied Black Snake	<i>Pseudechis porphyriacus</i>
Birds	
Australasian Grebe	<i>Tachybaptus novaehollandiae</i>
Australian Brush-Turkey	<i>Alectura lathamii</i>
Australian Bustard	<i>Ardeotis australis</i>
Australian King-parrot	<i>Alisterus scapularis</i>
Australian Magpie	<i>Cracticus tibicen</i>
Australian Wood Duck	<i>Chenonetta jubata</i>
Bassian Thrush	<i>Zoothera lunulata</i>
Brown Quail	<i>Coturnix ypsilophora</i>
Common Bronzewing	<i>Phaps chalcoptera</i>
Crested Pigeon	<i>Ocyphaps lophotes</i>
Crimson Rosella	<i>Platycercus elegans</i>

Eastern Rosella	<i>Platycercus eximius</i>
Eastern Spinebill	<i>Acanthorhynchus tenuirostris</i>
Emu	<i>Dromaius novaehollandiae</i>
Fantailed Cuckoo	<i>Cacomantis flabelliformis</i>
Flame Robin	<i>Petroica phoenicea</i>
Glossy Black-cockatoo	<i>Calyptorhynchus lathami</i>
Grey Fantail	<i>Rhipidura albiscapa</i>
Grey Teal	<i>Anas gracilis</i>
Hardhead	<i>Aythya australis</i>
Laughing Kookaburra	<i>Dacelo novaeguineae</i>
Leaden Flycatcher	<i>Myiagra rubecula</i>
Little Lorikeet	<i>Glossopsitta pusilla</i>
Masked Owl	<i>Tyto novaehollandiae</i>
Mistletoebird	<i>Dicaeum hirundinaceum</i>
Musk Lorikeet	<i>Glossopsitta concinna</i>
New Holland Honeyeater	<i>Phylidonyris novaehollandiae</i>
Noisy Friarbird	<i>Philemon corniculatus</i>
Pacific Black Duck	<i>Anas superciliosa</i>
Painted Button-quail	<i>Turnix varius</i>
Powerful Owl	<i>Ninox strenua</i>
Rainbow Lorikeet	<i>Trichoglossus haematodus</i>
Red Wattlebird	<i>Anthochaera caruncula</i>
Rufous Whistler	<i>Pachycephala rufiventris</i>
Sacred Kingfisher	<i>Todirhamphus sanctus</i>
Satin Bowerbird	<i>Ptilonorhynchus violaceus</i>
Satin Flycatcher	<i>Myiagra cyanoleuca</i>
Scarlet Robin	<i>Petroica boodang</i>
Silvereye	<i>Zosterops lateralis</i>
Stubble Quail	<i>Coturnix pectoralis</i>
Striated Pardalote	<i>Pardalotus striatus</i>
Superb Lyrebird	<i>Menura novaehollandiae</i>
Wedge-tailed Eagle	<i>Aquila audax</i>
White-naped Honeyeater	<i>Melithreptus lunatus</i>

Yellow-faced Honeyeater	<i>Lichenostomus chrysops</i>
Yellow-tailed Black-cockatoo	<i>Calyptorhynchus funereus</i>
Mammals	
Brown Antechinus	<i>Antechinus stuartii</i>
Bush Rat	<i>Rattus fuscipes</i>
Common Brushtail Possum	<i>Trichosurus vulpecula</i>
Common Ringtail Possum	<i>Pseudocheirus peregrines</i>
Common Wallaroo	<i>Macropus robustus</i>
Eastern False Pipistrelle	<i>Falsistrellus tasmaniensis</i>
Eastern Grey Kangaroo	<i>Macropus giganteus</i>
Feathertail Glider	<i>Acrobates pygmaeus</i>
Greater Glider	<i>Petauroides volans</i>
Koala	<i>Phascolarctos cinereus</i>
Long-nosed Bandicoot	<i>Perameles nasuta</i>
Red-necked Wallaby	<i>Macropus rufogriseus</i>
Short-beaked Echidna	<i>Tachyglossus aculeatus</i>
Spotted-tailed Quoll	<i>Dasyurus maculatus</i>
Sugar Glider	<i>Petaurus breviceps</i>
Swamp Wallaby	<i>Wallabia bicolor</i>
Fish	
Eel	<i>Anguilla reinhardtii</i>
Invertebrates	
New England Crayfish, Sutton's Crayfish	<i>Euastacus suttoni</i>

Plants	
Common name	Scientific name
Apple Berry	<i>Billardiera scandens</i>
Australian Indigo	<i>Indigofera australis</i>
Backwater Grevillea	<i>Grevillea scortechinii</i> subsp. <i>sarmentosa</i>
Beard Heath	<i>Leucopogon lanceolatus</i>
Bell-Fruited Mallee	<i>Eucalyptus codonocarpus</i>
Blackthorn	<i>Bursaria spinosa</i>
Blady Grass	<i>Imperata cylindrica</i>
Bluebell	<i>Wahlenbergia</i> spp.
Box-Leaf Wattle	<i>Acacia buxifolia</i>
Bracken Fern	<i>Pteridium esculentum</i>
Bridal Veil Orchid	<i>Dendrobium teretifolium</i>
Broad-Leaved Stringybark	<i>Eucalyptus caliginosa</i>
Bulbine Lily	<i>Bulbine bulbosa</i>
Bush Tomato	<i>Solanum</i> spp.
Chocolate Lily	<i>Dichopogon strictus</i>
Coast Banksia	<i>Banksia integrifolia</i> subsp. <i>monticola</i>
Common Buttercup	<i>Ranunculus lappaceus</i>
Diehard Stringybark	<i>Eucalyptus cameronii</i>
Dusky Fingers	<i>Caladenia fuscata</i>
Early Nancy	<i>Wurmbea dioica</i>
Fairy Aprons	<i>Utricularia dichotoma</i>
False Sarsaparilla	<i>Hardenbergia violacea</i>
Forest Goodenia	<i>Goodenia hederacea</i>
Fringe Lily	<i>Thysanotus tuberosus</i>
Fringed Midge Orchid	<i>Genoplesium fimbriatum</i>
Geebung	<i>Persoonia cornifolia</i>
Glycine	<i>Glycine</i> spp.
Grass Tree	<i>Xanthorrhoea glauca</i>
Greenhood Orchid	<i>Pterostylis</i> spp.
Grey Billy Buttons	<i>Craspedia canens</i>
Hairpin Banksia	<i>Banksia cunninghamii</i>

Hairy Speedwell	<i>Veronica calycina</i>
Hovea	<i>Hovea purpurea</i>
Jam Tarts	<i>Melichrus procumbens</i>
Kangaroo Grass	<i>Themeda triandra</i>
Ladies Tresses	<i>Spiranthes australis</i>
Lawyer Vine	<i>Smilax australis</i>
Leafy Purple Flag	<i>Patersonia glabrata</i>
Leek Orchid	<i>Prasophyllum</i> sp. aff. <i>odoratum</i>
Lemon Dove-tail	<i>Diuris abbreviata</i>
Manna Gum	<i>Eucalyptus viminalis</i>
Mint Bush	<i>Prostanthera</i> sp.
Mistletoe	<i>Amyema</i> spp.
Native Clematis/Headache Vine	<i>Clematis glycinoides</i> var. <i>glycinoides</i>
Native Daisy	<i>Brachyscome</i> spp.
Native Geranium	<i>Geranium solanderi</i>
Native Raspberry	<i>Rubus parvifolius</i>
Native Or Showy Violet	<i>Viola betonicifolia</i>
Ivy-Leaved Violet	<i>Viola hederacea</i>
Onion Orchid	<i>Microtis unifolia</i>
Pink Kunzea	<i>Kunzea obovata</i>
Potato Orchid	<i>Gastrodia sesamoides</i>
Prickly Broom Heath	<i>Monotoca scoparia</i>
Prickly Moses	<i>Acacia ulicifolia</i>
Slender Stackhousia	<i>Stackhousia viminea</i>
Slender Teatree	<i>Leptospermum brevipes</i>
Snow Gum	<i>Eucalyptus pauciflora</i>
Spiny Matt Rush	<i>Lomandra longifolia</i>
Sun Orchids	<i>Thelymitra</i> sp.
Vanilla Lily	<i>Arthropodium milleflorum</i>
Wombat Berry	<i>Eustrephus latifolius</i>
Yellow Buttons	<i>Chrysocephalum semipapposum</i>

Appendix 7.1

Fire responses of individual shrub and tree taxa

S = seed (from soil or canopy stored seed), R = resprout (from root, basal, stem or apical buds)

Species	Observed fire response	Literature fire response (Hunter 2001, 2003b; Clarke <i>et al.</i> 2009)
<i>Acacia brownii</i>	S	R
<i>Acacia filicifolia</i>	S R	R
<i>Acacia gunnii</i>		R
<i>Acacia rubida</i>	S	R
<i>Acacia venulosa</i>		S R
<i>Aotus subglauca</i>	S	R
<i>Banksia integrifolia</i>	S R	S R
<i>Banksia marginata</i>	S	S
<i>Billardiera scandens</i>	R	R
<i>Bossiaea neoanglica</i>	S	R
<i>Bossiaea scortechinii</i>	S	R
<i>Brachyloma daphnoides</i>		R
<i>Bursaria spinosa</i>	R	R
<i>Correa reflexa</i>		S
<i>Cryptandra amara</i>		R
<i>Dillwynia retorta</i>	S	S
<i>Dillwynia</i> sp.	S	
<i>Eucalyptus caliginosa</i>	R	R
<i>Eucalyptus caliginosa</i>	R S	R
<i>Eucalyptus cameronii</i>		R
<i>Eucalyptus laevopinea</i>		R
<i>Eucalyptus nobilis</i>	R	R

<i>Eucalyptus nova-anglica</i>	R	R
<i>Eucalyptus obliqua</i>	R	R
<i>Eucalyptus pauciflora</i>		R
<i>Eucalyptus radiata</i>	R	R
<i>Eucalyptus</i> sp.	S	
<i>Exocarpos cupressiformis</i>		R
<i>Gompholobium huegelii</i>	S	R
<i>Grevillea scortechinii</i> subsp. <i>sarmentosa</i>	S	S R
<i>Hardenbergia violacea</i>	S	S
<i>Hibbertia riparia</i>	S	R
<i>Hovea heterophylla</i>	S	R
<i>Hovea purpurea</i>	S	S
<i>Indigofera australis</i>		R
<i>Leptospermum brevipes</i>	R	R
<i>Leucopogon fraseri</i>	S	R
<i>Leucopogon lanceolatus</i>	R	R
<i>Logania albiflora</i>	S	R
<i>Lomatia fraseri</i>	R	R
<i>Lomatia silaifolia</i>	R	R
<i>Melichrus procumbens</i>	R	R
<i>Melichrus urceolatus</i>	S	R
<i>Mirbelia confertiflora</i>	S	S R
<i>Monotoca scoparia</i>	S R	R
<i>Persoonia cornifolia</i>	S	S, R
<i>Persoonia procumbens</i>	S	R
<i>Petrophile canescens</i>	S	R
<i>Pimelea linifolia</i>	S	S
<i>Polyscias sambucifolia</i>	R	R

<i>Rhytidosporum procumbens</i>		R
<i>Rubus anglocandicans</i>	S	S
<i>Smilax</i>	R	R
Unknown shrub 1	S	
Unknown shrub 2	S	
Unknown shrub 3	S	
Unknown shrub 4	S	
Unknown shrub 5	R	