Grassy Eucalypt Woodlands Wiyn Murrup Monitoring Program (2020–2023)

Evaluation report

B. Farmilo, A. Jackson, Wadawurrung Traditional Owners Aboriginal Corporation

June 2023

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Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

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Front cover photo: A fire torch used to move fire during Wiyn Murrup (Source: Jess Lill)

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Evaluation report

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Contents

Summary

Context: The Grassy Eucalypt Woodlands of the Victorian Volcanic Plains comprise a critically endangered plant community that has undergone a dramatic decline in both extent and condition since European arrival. Immediate action is required to halt the decline and improve condition. Cultural burning (here referred to as Wiyn Murrup, simplified from the Wadawurrung phrase *Wiyn Murrup Yangarramela*, meaning 'fire spirit comes back') is a Wadawurrung cultural practice that is being used to restore the health of Country. It can provide important ecological functions (e.g. reduce grassy biomass accumulation, improve vegetation structure and give an advantage to native species over weeds), as well as cultural values, and be used to improve woodland condition.

Aims: We aimed to establish a partnership between Aboriginal people (Wadawurrung Traditional Owners Aboriginal Corporation; WTOAC) and non-Aboriginal government staff, researchers and corporations, to design and implement a monitoring program to explore the role of Wiyn Murrup on ecological outcomes. The monitoring program attempts to generate information relevant to both Aboriginal and non-Aboriginal stakeholders.

Methods: To build the partnership, we used interviews and a meeting on Country to facilitate knowledge sharing and to explore the additional outcomes beyond vegetation change (both benefits and challenges) of the project. We used a rapid monitoring framework developed by Farmilo et al. (2021) to monitor changes to the vegetation at three woodland sites in both autumn and spring for three consecutive years. The monitoring includes pairs of treatment sites (i.e. sites with Wiyn Murrup) and control sites.

Results: Wiyn Murrup led to an increase in bare ground cover and a decrease in grassy biomass, and these changes persisted for one year after fire. Most other attributes (e.g. fine fuels, native and exotic species cover) were dynamic over time, but not strongly associated with Wiyn Murrup in the first phase of monitoring.

Time on Country to attend meetings, conduct monitoring, and apply Wiyn Murrup has established an effective partnership and has improved all participants understanding of when to apply Wiyn Murrup (i.e. the burn window), how the ecosystem responds to Wiyn Murrup, and what additional land management might be needed to heal Country in the long-term. In addition, trust, active listening and effective relationships between project partners have contributed to WTOAC being able to determine more freely where, when and how they apply Wiyn Murrup. However, some inherent challenges remain and require further understanding to ensure the best outcomes for Wadawurrung people and the environment.

Conclusions and implications: The monitoring program has (1) produced important knowledge about the initial effects of Wiyn Murrup on woodland vegetation, (2) fostered a balanced relationship between WTOAC, government agencies and researchers built on trust and active listening, and (3) identified a path forward in which the monitoring should continue and efforts should be made to shift WTOAC agency and decision-making towards a more balanced and respectful position.

Future monitoring should consider adding new sites (perhaps with a native-dominated understorey) into the monitoring program to gain further insights into the role of Wiyn Murrup in healing Country and how this trajectory changes in woodlands with a different starting condition in the understorey.

Frequent (annual or biennial) application of Wiyn Murrup should continue at the monitoring sites to restore the health of Country. As well as the cultural benefits of Wiyn Murrup, it is anticipated that the cultural practice (in concert with other land management practices; i.e. weed control) will encourage the competitive advantage of native species, improve vegetation structure, and by extension improve woodland condition in the long term (> 10 years).

1 Introduction

1.1 Caring for Country

Fire is one of many cultural practices used by Aboriginal people to care for and celebrate Country. This care for Country resulted in a diverse and productive environment. However, the use of fire by Aboriginal people in Victoria was restricted soon after the arrival of Europeans (O'Kane et al. 2019). While a desire to apply cultural fire to landscapes has always remained important for Aboriginal people in Victoria, only recently have governments, land managers and decision-makers begun to consider how ecosystems were once burnt by Aboriginal people and how this knowledge can be applied in a contemporary context. The reinvigoration of cultural fire aims to ensure better management of ecosystems in the future, while supporting Aboriginal self-determination. There are numerous benefits to cultural fire practices implemented by Aboriginal people (e.g. health and wellbeing, cultural and social, economic and environmental; Davies et al. 2010; Hill et al. 2013; Maclean et al. 2018). However, this report focuses on the influence of cultural fire — *Wiyn Murrup Yangarramela* ('fire spirit comes back'; hereafter Wiyn Murrup: WTOAC 2020) — on environmental and social-cultural benefits, which are almost always interlinked (e.g. Walsh et al. 2013).[1]

1.2 Wiyn Murrup ('fire spirit comes back')

Fire has an important role in regulating natural grassy ecosystems and maintaining ecosystem condition in the Victorian Volcanic Plains (VVP). Regular fires remove the dominant grassy biomass (often the summer-growing grass *Themeda triandra*) and leaf litter. This removal creates gaps between the grass tussocks that allow diverse wildflowers and culturally important plants to germinate, grow and reproduce (Morgan 2015) and provides habitat for fauna (Scroggie et al. 2019). Wiyn Murrup can provide these ecological outcomes while also reaffirming cultural connections to Country and healing Country and people (WTOAC 2020).

If fire is suppressed, grassy biomass can quickly accumulate (in 5–10 years: Morgan and Lunt 1999), particularly in mesic and productive environments like the southern Victorian Volcanic Plain (Morgan 2015). Rapid biomass accumulation can affect the regulation of nutrient cycling, population dynamics and animal habitat suitability (Lunt and Morgan 2002), ultimately leading to a diagnosis of 'sick' Country by Aboriginal people and degradation of cultural connection. The accumulated biomass also equates to fuel and can increase the fire risk in summer (Cruz et al. 2018). If fire and other methods of biomass removal are suppressed for long periods, the dominant tussock grasses (e.g. Kangaroo Grass, *Themeda triandra*) can also succumb to the effect of biomass accumulation (Morgan 2015), causing a thick layer of leaf litter which can be difficult to reverse (Morgan and Lunt 1999).

More recently, managers of natural grassy ecosystems (on both public reserves and private land) are exploring the utility of Wiyn Murrup as a way of maintaining and enhancing Aboriginal culture and environmental values (FVTOC 2019). Wiyn Murrup intends to primarily care for Country and improve cultural values (which often overlap with ecological values; e.g. biodiversity) by using a traditional approach to burning (i.e. slow, cool and patchy fires; Figure 1) that differs from most contemporary 'fuel-reduction' approaches (faster, hotter and homogeneous fires; Steffensen 2020). However, the actual application of Wiyn Murrup remains embedded within processes and regulations administered by government authorities and non-Aboriginal people (Rawluk et al. 2023) representing a power imbalance, or challenge to Aboriginal agency and self-determination, that requires continued work to address.

[1] The term 'Aboriginal' is used to describe the First Nations peoples of Australia. We use the term 'Wyn Murrup' to describe a specific type of burning applied by WTOAC where cultural values (which often include ecological outcomes), rather than fire hazard reduction or specific ecological outcomes, are the desired outcomes of the burning. WTOAC applies various types of burning, but only Wiyn Murrup applies to the results of this study. In other areas of Australia and globally, various terms are used to describe Aboriginal fire management and its application, such as Indigenous or traditional fire management, Aboriginal or Indigenous burning, Indigenous wildfire management, cultural fire and burning of Country.

Wiyn Murrup has been, and continues to be, applied by Wadawurrung Traditional Owners Aboriginal Corporation (WTOAC) in this context to heal 'sick' Country. This is often a lengthy process whereby gains (in terms of Country health, vegetation condition, biodiversity value) are slow initially as the foundations for future burning are laid (removing litter layer, changing nutrient cycling, adjusting the balance of woody species, removing weeds). Also, demographic limitations cause lag effects that affect the recovery of desirable species (Albrecht et al. 2019). These species, which are often scarce, need effective recruitment to thrive as Country heals. Wiyn Murrup may also need to be supplemented with additional actions (e.g. tree thinning, weed control), given the modified landscape within which Country now exists. New knowledge is essential to ensure the various aims of Wiyn Murrup are being realised by WTOAC and the broader community.

Figure 1. Wiyn Murrup applied to Bakers Lane Reserve by Wadawurrung Traditional Owners Aboriginal Corporation (WTOAC), showing numerous ignition points that result in a patchy fire that trickles through the landscape.

1.3 Project context

The National Landcare Program Phase 2 (NLP2; the Australian Government's long-standing commitment to natural resource management) funded partnerships between the Australian Government and stakeholders (e.g. governments, industry, Aboriginal communities and individuals) to protect and conserve Australia's natural resources and biodiversity (Australian Government 2023). The Corangamite Catchment Management Authority (CMA) acquired funding from NLP2 for the 'Protecting the Victorian Volcanic Plains' project. This project aimed to protect remnant habitat, species and communities in the Victorian Volcanic Plains (VVP) through enhancement of linear remnants, cultural burning practices (and associated reciprocal knowledge exchange), and a landholder stewardship program (Corangamite CMA 2021). The project aims to improve the condition of federally listed threatened ecological communities under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (e.g. Natural Temperate Grasslands and Grassy Eucalypt Woodlands of the Victorian Volcanic Plains) within the Corangamite CMA region (Corangamite CMA 2021).

1.4 Progress reporting

This report documents a partnership between Aboriginal people (WTOAC) and non-Aboriginal government staff, researchers and corporations, and the outcomes from the initial phase of a monitoring program which assessed changes in Grassy Eucalypt Woodland condition in response to Wiyn Murrup. This report should be considered ‘preliminary’ where early trends are discussed, achievements indirectly associated with the monitoring program are highlighted (e.g. social components), and challenges in applying a partnership approach to healing Country are identified. With this view, recommendations for improvement are made to ensure the longer-term aspirations for the project can be realised.

2 Methods

2.1 Grassy Eucalypt Woodland

Grassy ecosystems (e.g. woodlands, grassland and wetlands) on the Victorian Volcanic Plains (VVP) have provided Aboriginal people with essential resources (e.g. food, fibre, clothing, building material, medicine) and a place to practice and celebrate culture for millennia.

The Grassy Eucalypt Woodlands of the Victorian Volcanic Plains community (hereafter GEW) occurs on undulating topography with relatively fertile and rocky soils (Sinclair et al. 2018). It is often dominated by eucalypt trees and has an understorey of sparse mid-storey shrubs and a diverse ground layer of grasses and herbs (TSSC 2009a, b; DSEWPAC 2011; Figure 2).

Figure 2. Grassy eucalypt woodland on undulating plains showing a large old tree in the background. The vegetation also shows Eucalypt recruitment in the foreground, intact coarse woody debris (i.e. logs) and high native understorey cover. It is therefore considered to be moderate to good condition based on a contemporary definition of condition (Sinclair et al. 2018).

The ecological community has been significantly modified due to suppression of Traditional management practices (e.g. Wiyn Murrup), and its extent and condition have been reduced significantly by the direct effects (e.g. land clearance) and indirect effects (e.g. fragmentation and weed invasion) of agricultural intensification and urbanisation since the arrival of Europeans (Prober et al. 2009). As a result, GEW is federally listed as critically endangered, which suggests the risk of extinction of the community is high if no action is taken to conserve it (TSSC 2009a). This sentiment is supported by Traditional Owner assessments where many remaining remnants of GEW are considered ‘sick’ due to a build-up of predominantly exotic grassy biomass (in productive areas) and leaf litter (in less productive areas), an increase in the cover of exotic or native weeds, mass germination and survival of juvenile trees, and dieback of the tree canopy, among other symptoms.

2.2 Wiyn Murrup program

We established a partnership between Aboriginal and non-Aboriginal government staff, researchers and WTOAC staff that led to design and implementation of a monitoring program.

The focus of the Wiyn Murrup program (Farmilo et al. 2021) is to gain a better understanding of the role of Wiyn Murrup in maintaining and improving the condition of GEW in south-eastern Australia, and to establish a framework for sharing knowledge (two ways of knowing: Reid et al. 2021).

2.3 Partner self-assessment

The Wiyn Murrup program considered social and cultural benefits of Wiyn Murrup and the monitoring program in terms of knowledge exchange (between all partners; WTOAC Wiyn Murrup and Natural Resources Management (NRM) teams, Corangamite CMA Protecting the Victorian Volcanic Plains team, and Department of Energy, Environment and Climate Action (DEECA) Natural Environment Programs and ARI) and the bolstering of cultural identity for WTOAC. It also considered the challenges faced when implementing Wiyn Murrup and the monitoring program. It was not feasible to predict what the outcomes might be or how strongly they would be influenced by the program. However, numerous benefits to all partners and various challenges (particularly for WTOAC) became apparent through meetings and interviews conducted as part of the monitoring program, and they are noted in this report.

A group of nine Aboriginal and non-Aboriginal WTOAC members, government staff and researchers with established interests in Wiyn Murrup were identified. A meeting on Country (the You Yangs monitoring site) took place after two years of monitoring. As a group, participants discussed:

- the ecological changes following Wiyn Murrup,
- the skills developed and opportunities taken to increase knowledge and improve knowledge exchange, and
- the challenges faced by WTOAC when navigating the partnership approach to applying Wiyn Murrup and associated monitoring.

Following this, interviews were undertaken with five members of WTOAC (including three members from the meeting on Country and two members involved in the original monitoring program design), one DEECA staff member and two CMA staff members. Interviews were conducted in three separate group interviews for each of the partner agencies or corporations. Each interview was held with partners as three groups representing each agency or corporation, was conducted verbally, and was facilitated by ARI. Interviews used prompted questions to explore expected timelines for ecological responses (to guide evaluation reporting) and to explore comments made in the meeting on Country in more detail. Each participant was informed of the purpose of the interview and participants gave informed prior consent to use the information gained in the interviews. Each participant was given an opportunity to review the interview content used in this report. All the content from the interviews are characterised at the level of agency or WTOAC to give participants anonymity.

2.4 Monitoring implementation

The monitoring program was designed to measure vegetation condition using coarse and rapid methods, with the intention that it could be easily implemented by CMA staff and WTOAC members with minimal training from the ARI. It was anticipated that the monitoring component would proceed beyond the life of the Protecting the Victorian Volcanic Plains project (i.e. beyond 2023) to evaluate longer-term outcomes, gain further insights into the influence of Wiyn Murrup on GEW condition, and to continue to bolster knowledge exchange.

2.4.1 Monitoring sites

Three monitoring sites were established to monitor changes in vegetation and ground cover in response to Wiyn Murrup (Figure 3). The selection of particular monitoring sites was guided by different considerations, and each monitoring site has a different disturbance history, tenure and landscape context (Table 1).

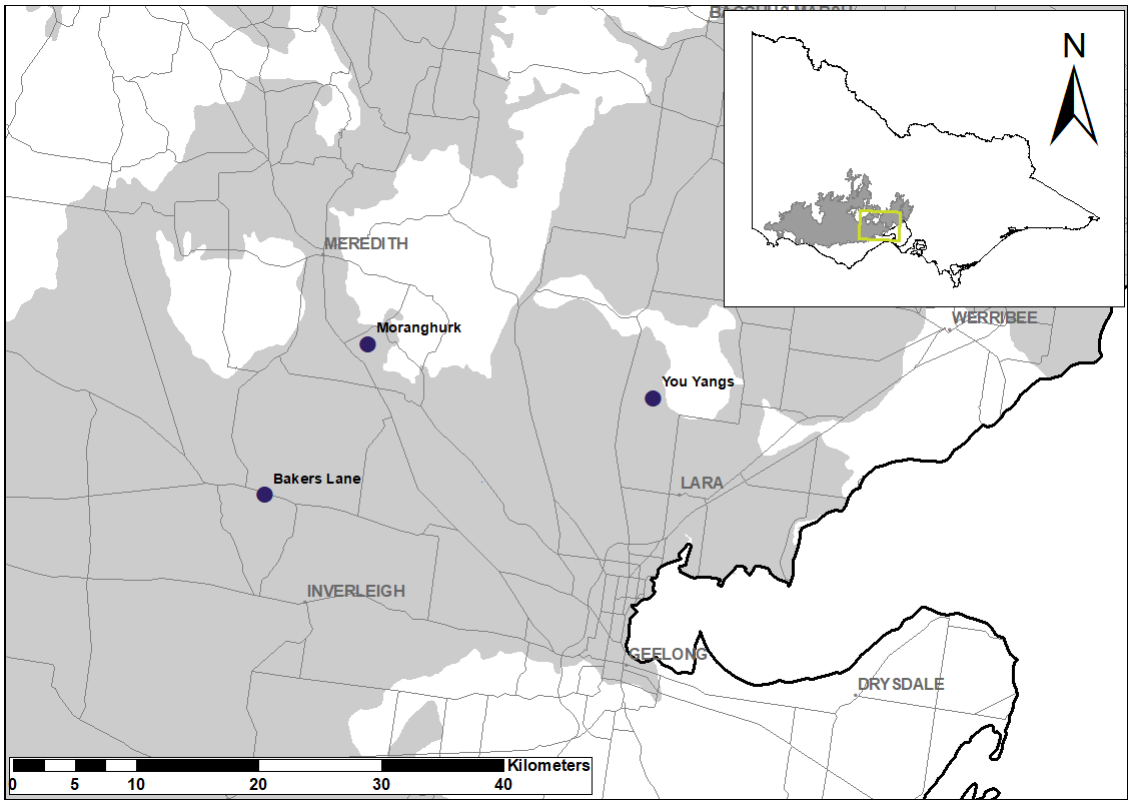

Figure 3. Map of the study area showing the extent of the Victorian Volcanic Plains (grey shading) and the locations of monitoring sites.

The Bakers Lane monitoring site is a relatively small area of GEW located near the town of Teesdale (Table 1; Figure 3). The site is characterised by large old River Red Gums (*Eucalyptus camaldulensis*) with numerous recruiting trees, an understorey dominated by exotic perennial grasses (e.g. Phalaris) and a low abundance and diversity of native herbaceous species (Smithyman 2020; Table 1). The site was one of several reserves that fit the criteria and were proposed at the beginning of the project. This reserve was deemed suitable due to its small size, its native vegetation values and ongoing management by Golden Plains Shire Council. A previous application of Wiyn Murrup by WTOAC in 2017 (Smithyman 2020) made this a desirable location to continue cultural practices and improve the health of Country. Monitoring was established in April 2021.

The You Yangs monitoring site is part of the You Yangs Regional Park and is managed by Parks Victoria. It is characterised by moderate-sized trees (*Eucalyptus* spp.), wattles (*Acacia* spp.) and an understorey with moderate native cover (Table 1). Two weed species, representing different life histories and growth forms, are prominent: Boneseed (*Chrysanthemoides monilifera*) and Annual Veldt-grass (*Ehrharta longiflora*). The site was selected because it has significant cultural heritage due to the proximity to the You Yangs (Wurdi Youang) and Hovells Creek, and associated song lines. Monitoring was established in April 2021.

The Moranghurk monitoring site is a large rural property on private land near the town of Lethbridge, with large old Yellow Gums (*Eucalyptus leucoxylon*) and an understorey dominated by native and perennial grasses (Table 1; Figure 3). WTOAC assessed a number of private properties in the Corangamite CMA stewardship program and selected this site due to the proximity to the Moorabool River and associated escarpments, which have significant cultural value to Wadawurrung people. Monitoring was established in April 2022, but monitoring sites were exposed to Wiyn Murrup only recently (May 2023) so the dataset

related to this site could not be used to assess the outcomes of Wiyn Murrup, which uses data collected prior to April 2023.

Table 1. Features and disturbance history of monitoring sites.

Remnant size (ha)	Burn footprint (ha)	Landscape context	Dominant tree species	Disturbance history	Recent disturbance history
Bakers Lane (public)					
3.7	3.0	Reserve in rural town	River Red Gum (*E. camaldulensis*)	No livestock grazing Burning: March 2012 April 2013 *April 2017 October 2019	Burning: *May 2021 *May 2023
You Yangs (public)					
17.5	4.5	Part of You Yangs Regional Park adjacent to timber plantation and Hovells Creek	River Red Gum (*E. camaldulensis*) and Yellow Gum (*E. leucoxylon*)	No livestock grazing No burning	Burning: *April 2021 *May 2022 *May 2023
Moranghurk (private)					
40.0	16.0	Rural property with extensive GEW cover adjacent to escarpment and Moorabool River	Yellow Gum (*E. leucoxylon*)	Livestock grazing until 2009; again in 2022 Some macropod grazing No burning	Burning: *May 2022 [did not affect monitoring site] *May 2023

* Indicates burning that was undertaken using the principles of Wiyn Murrup.

2.4.2 Rainfall

Rainfall across the study area has gradually increased over the period of monitoring (average annual rainfall across both weather stations: 2021 – 655 mm; 2022 – 873 mm; Figure 4).

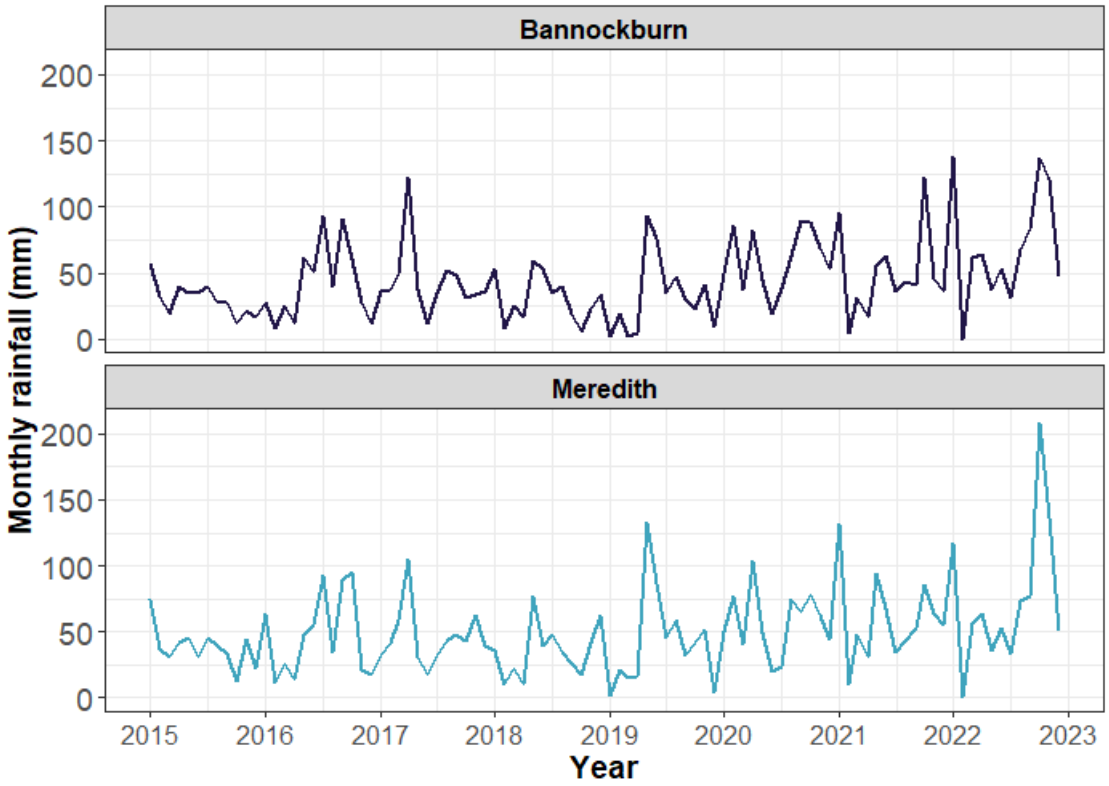

Figure 4. Rainfall for the study area based on monthly rainfall data (BOM 2023) for two weather stations.

Bannockburn – Station # 087147, average annual rainfall 1973–2022 = 555 mm.
Meredith – Station # 089025, average annual rainfall 1875–2022 = 669 mm.

2.4.3 Management

Each monitoring site has had Wiyn Murrup applied at least twice since monitoring was established (Table 1). The You Yangs site has been burnt three times in the area where monitoring is conducted. The sites at Bakers Lane and Moranghurk have been burnt twice; however, the Wiyn Murrup site at Moranghurk was burnt only in May 2023, following the collation of the dataset used in this report. In all cases the fire was slow-moving and patchy (Figure 1).

Between April 2021 and May 2022 a large area of Boneseed (*Chrysanthemoides monilifera*) at the You Yangs site was removed using hand pulling. Most of the plants were within the Wiyn Murrup footprint. In addition, herbicide spraying was applied to numerous perennial weed species (Boneseed; Serrated Tussock, *Nassella trichotoma*; Blanket Weed, *Aizoon pubescens*; and Bridal Creeper *Asparagus asparagoides*) in October 2022.

Weed control also took place at Moranghurk in March 2023, prior to the most recent burn. Herbicide spraying was applied to numerous weed species, including Horehound (*Marrubium vulgare*), various thistles (e.g. *Cirsium* spp., *Carduus* spp., *Sonchus* spp.) and Briar Rose (*Rosa rubiginosa*). No weed control was applied at Bakers Lane over the monitoring period.

2.4.4 Measures

While the concept of vegetation condition is complex (e.g. Sinclair et al. 2018), a careful attempt was made to create a rapid monitoring method that can identify changes in vegetation condition and values important to Aboriginal people over time. The method, and the values it measures, was reviewed widely among project partners (WTOAC, DEECA) and ecologists at ARI. Significantly, the monitoring program acknowledges the cultural, spiritual and ecological benefits of Wiyn Murrup for Wadawurrung people.

The monitoring framework (Farmilo et al. 2021) is freely accessible online and provides a detailed account of the methods, their context in the literature, and justifications for their inclusion. Monitoring occurred twice a year in autumn and spring. Here we provide a brief overview of the methods.

Three scales of assessment are used (to account for different structural components of GEW: trees to grasses) to ensure the monitoring data can inform both short-term (3 years) and longer-term (> 10 years) land management goals and targets (Figure 5). The resolution and scale of the data varies, depending on the variable of interest:

1. Monitoring plot (0.4 ha; e.g. indicator species, trees, understorey),
2. Large quadrat assessments (20 x 20 m quadrat; e.g. large shrubs, fire attributes),
3. Small quadrat assessments (1 x 1 m quadrats; e.g. ground cover, biomass).

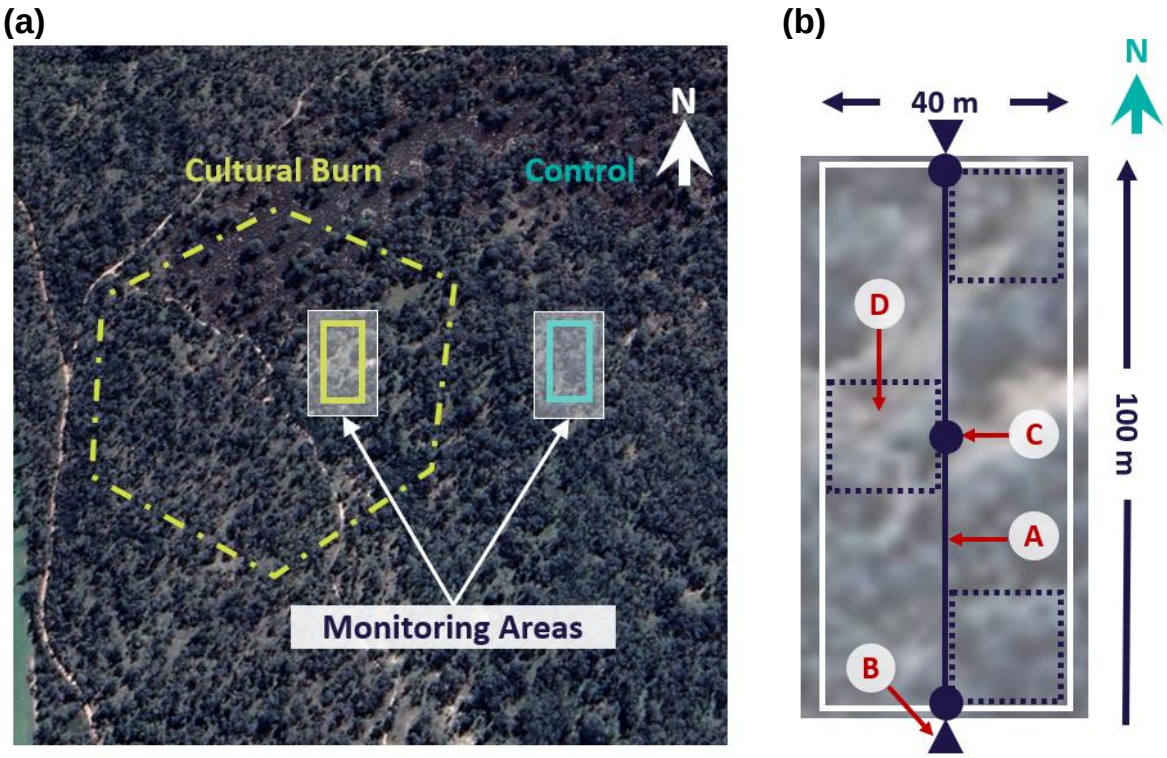

Figure 5. Monitoring plots showing (a) position in relation to cultural burn and (b) monitoring design for the 50 x 100 m monitoring plot showing: 'A' = 100 m main transect; 'B' = site photo points and permanent markers at both ends of the main transect (indicated by ▲); 'C' = three canopy photos (indicated by ● at 0 m, 50 m and 100 m); 'D' = three fixed 20 x 20 m large quadrats. In the four internal corners of each large quadrat a 1 x 1 m small quadrat was assessed.

It was anticipated that remnants earmarked for Wiyn Murrup would have adjacent areas of GEW that will remain unburnt, and these areas would be important as control sites (Duncan and Reich 2016) to enable evaluation using a formal experimental design. This approach will allow the separation of Wiyn Murrup management effects from any other temporal changes.

The You Yangs and Moranghurk monitoring sites have complete control sites (which mirrors the same arrangement and replication of quadrats as the monitoring site affected by Wiyn Murrup). The Bakers Lane monitoring site has a control site that is reduced in size (only a single large quadrat with four internal small quadrats) due to the small nature of the reserve.

The vegetation and ground cover attributes selected for defining vegetation condition, the justification for their inclusion, the expected time-lines for realising improvement and the monitoring methods are detailed in Tables 2, 3 and 4.

Table 2. The GEW target variables and the reasons for their inclusion.

Variable	Justification for inclusion
Vegetation theme	
1. Tree cover	*Eucalyptus* species are the dominant trees, and a defining feature of GEW. Their cover is important for the integrity of the ecological community (TSSC 2021) and have important cultural values for providing long-term environmental sustainability (Steffensen 2020).
2. Tree health	Health can be linked to demographic assessments as an indicator of decline to allow intervention before degradation processes becomes established.
3. Target native shrubs, small trees (non-eucalypt)	This structural component is much depleted. Target species include large shrubs such as *Acacia*, *Allocasuarina*, *Banksia*, *Bursaria*, *Cassinia*, *Exocarpos* and *Melicytus* which provide resources for animals and Traditional values (e.g. food, tools: Gott 2008)
4. Woody exotics	Woody weeds (e.g. Boneseed, African Box-thorn) may form dense stands that exclude other species, alter the structure of the vegetation and change fire behaviour.
5. Understorey	Understorey components can be useful indicators of site disturbance and are important for identifying and recording future improvements in site condition. Native understorey species also provides numerous values to both western and Traditional views of GEW.[2]
6(a). Cover of desirable understory indicator species	The identity of desirable indicator plant species (Table A4) may be site-specific (maximum four species / monitoring plot). The species should represent both western and Traditional values. Western values: • foundational species, which play roles in nutrient dynamics (e.g. *Themeda triandra*: Prober et al. 2009) • threatened species, which have been in decline due to livestock grazing and/or biomass accumulation (e.g. native herbs: Dorrough et al. 2004) Traditional values: • resource species which provide food, medicine, textiles • totem species which are important cultural symbols.
6(b). Cover of undesirable understory indicator species	The identity of undesirable indicator species (Table A4) may be site-specific (maximum four species / monitoring plot). The species should represent threats to both western and Traditional values. Typically, all weeds present a threat to both western and Traditional views of GEW condition. However, the types of weeds may be weighted differently and should be considered during selection.

[2] The term 'western' is used to describe the non-Aboriginal knowledge system which is often derived from observation followed by the testing of predictions or hypotheses. The term does not exclude knowledge from 'non-western' countries (e.g. China, Japan).

Variable		Justification for inclusion
Ground Cover theme		
7.	Length of coarse debris	Coarse debris (e.g. logs) provide habitat to a range of mammals, reptiles and invertebrates. The amount of debris is related to the abundance of some native animal species (MacNally et al. 2001). Debris also affects soil conditions for plants. Ideally, fire does not reduce the amount of coarse debris dramatically (Steffensen 2020) as it takes many years to regenerate.
8.	Cover of bare ground or soil crust	Bare ground is necessary for the recruitment of many native plants (Morgan 1998) and is an indicator of the health of Country (Steffensen 2020). Soil crust can prevent/reduce soil erosion (Williams et al. 1995; Eldridge and Kinnell 1997)
9.	Cover of leaf litter	The build-up of leaf litter can inhibit germination for wildflowers and other small plants.
10.	Biomass	The build-up of grassy biomass can change fire behaviour and deplete resources (e.g. light: Morgan 2015) for wildflowers and other small plants

2.4.5 Key evaluation questions

A set of key evaluation questions (KEQs; Table 3) was established as part of the monitoring framework (Farmilo et al. 2021) to guide evaluation. Frequently the KEQs represent long-term objectives for the work and some may only be realised after 5–20+ years. A subset of KEQs were selected (using both an ecological and traditional knowledge lens to predict short-term biological changes in response to Wiyn Murrup) and assessed to evaluate whether Wiyn Murrup is affecting short-term (two years) outcomes. All other KEQs were deemed long-term aspirations for the monitoring program and will be evaluated at a later stage when the timelines align with expected responses (Table 3).

For all management objectives (e.g. increase in understorey condition) there are one or more KEQs that were proposed that relate to GEW condition (e.g. has species richness of understorey life forms increased?). In turn, each KEQ has an ecological indicator and measure which are used to determine whether the objective is being achieved or not.

Most KEQs incorporate an anticipated direction of change (i.e. increase or decrease) that relate to long-term aspirations. Given these expectations are developed with a long-term view, where knowledge is obtained and management changed accordingly (i.e. adaptive management), no change, or a change in a direction not anticipated, should not be considered a failure of management at this point in time.

Table 3. Summary of the key evaluation question, targets, response timelines (incorporating both western and Traditional views), justification for whether assessment was undertaken in this report and a brief note on the outcomes based on the monitoring data.

Management objective	Key evaluation questions	Target / Benchmark	Response timeline*	Δ Assessed?	Justification for assessment	Outcome**
Improve health of tree population	Is tree canopy cover in line with the benchmark?	10–20% canopy cover. Canopy cover should not be consumed by fire.	10–20 years	No	Wiyn Murrup should not directly cause mortality of trees. Response timeline outside monitoring period.	Not assessed
	Has tree health been improved?	Good-Excellent. Maintenance of tree health is adequate if health good-excellent pre-burning.	5–20 years	No	Wiyn Murrup should not directly cause mortality of trees. Response timeline outside monitoring period.	Not assessed
	Has tree recruitment been improved?	Recruitment is ideally continuous without forming dense stands of single-aged individuals.	0–5 years	Yes	Heat and smoke from fire can promote germination. Recurrent fire can also kill seedlings.	**Maintained**
Reinstate sparse large shrub/small tree layer	Is abundance of large shrubs/small trees in alignment with benchmark?	5% cover. Site may either increase (where pre-burning cover is low) or decrease (where pre-burning cover is > 10% cover).	5–20 years	No	Wiyn Murrup does not directly cause mortality of adult small trees and large shrubs.	Not assessed
	Has shrub/small tree recruitment (i.e. presence of seedlings) been improved?	Recruitment is ideally continuous without forming dense stands of single-aged individuals.	0–5 years	Yes	Heat and smoke from fire can promote germination. Recurrent fire can also kill seedlings.	**Maintained**

Management objective	Key evaluation questions	Target / Benchmark	Response timeline*	∆ Assessed?	Justification for assessment	Outcome**
Reduce cover of woody weeds	Has abundance of woody weeds decreased?	0% cover. Ideally, woody weeds are absent from GEW sites.	5–10 years	Yes	Wiyn Murrup does not cause mortality of adult woody weeds. Weed control applied and could fast track response.	**Maintained**
	Has recruitment of woody weeds decreased?	Ideally, woody weed seedlings are absent from GEW sites.	0–5 years	Yes	Heat and smoke from fire can promote germination. Recurrent fire can also kill seedlings.	**Maintained**
Increase understorey condition	Has understorey score increased?	> 90% life forms present (Understorey Score 15–25).	5–20 years	No	The metric understorey score is quite coarse and not expected to respond to Wiyn Murrup within the timelines of the monitoring data.	**Not assessed**
	Has species richness of understorey life forms (each assessed separately) increased?	Richness is higher than the pre-burning richness.	2–20 years	Yes	Wiyn Murrup can reduce mulching effect of litter, and competition from exotic plant species and native plant biomass.	**Maintained**
	Has cover of understorey life forms (each assessed separately) increased?	Cover is higher than the pre-burning cover.	2–20 years	Yes	Wiyn Murrup can reduce mulching effect of litter, and competition from exotic plant species and native plant biomass.	**Maintained**

Management objective	Key evaluation questions	Target / Benchmark	Response timeline*	∆ Assessed?	Justification for assessment	Outcome**
Increase cover of desirable understory indicator species	Has abundance of desirable understorey indicator species increased?	Cover is higher than the pre-burning cover.	2–20 years	Yes	Wiyn Murrup can reduce mulching effect of litter, and competition from exotic plant species and native plant biomass.	**Maintained**
Decrease cover of undesirable understory indicator species	Has abundance of undesirable understorey indicator species decreased?	Cover is lower than the pre-burning cover.	2–20 years	Yes	Wiyn Murrup can cause mortality of exotic annual grasses and make weed control of perennial grasses and herbs more effective by increasing detectability and reducing off-target impacts.	**Maintained**
Maintain woody debris	Is the length of logs in line with the benchmark?	25 m / large quadrat. Logs should not be consumed by fire.	5–20 years	No	Wiyn Murrup protects logs from burning to prevent soil heating and to retain fauna habitat.	**Not assessed**
Modify ground cover	Has cover of bare ground increased?	Cover is higher than pre-burning cover.	2–20 years	Yes	Wiyn Murrup can reduce litter cover and expose bare ground.	**Increased**
	Has cover of organic litter decreased?	< 10% litter cover.	2–20 years	Yes	Wiyn Murrup can reduce litter cover.	**Maintained**
	Has cover of biological soil crust /	10-20% biological soil crust cover.	2–20 years	Yes	Wiyn Murrup can expose bare ground which can be colonised by soil	**Maintained**

Management objective	Key evaluation questions	Target / Benchmark	Response timeline*	Δ Assessed?	Justification for assessment	Outcome**
	moss been modified?				crust / cryptogamic organisms.	
Reduce grassy biomass	Has grassy biomass decreased?	Biomass is lower than pre-burning biomass.	2–20 years	Yes	Wiyn Murrup can reduce grassy biomass.	**Decreased**
Reduce fuel hazard	Has fuel hazard decreased?	Fuel hazard is lower than pre-burning state.	2–20 years	Yes	Wiyn Murrup will likely only influence surface fine fuels so this component of fuel hazard will be assessed.	**Maintained**

* Response timelines are based on average climate conditions, absence of stochastic events (e.g. herbivore/disease outbreak, windstorm, wildfire) and maintenance of current management actions (Wiyn Murrup and weed control), and assumes no reintroduction of native species.

** Colour in 'Outcome' column means: improvement – green, maintenance – black, not assessed – grey.

Δ Denotes 'change over time'

Table 4. Brief description of variables, measurements and monitoring methods.

Variable	Measurement	Method	Scale of assessment
Tree cover	Canopy photographs	Canopy photopoints.	3 photo points along each central transect (Figure 4b)
Tree health	Tree assessments	Assess crown extent, crown density, tree life stage and scorch height.	10 live mature trees across the monitoring plot
Tree recruitment	Number of seedlings	Estimate the number of seedlings according to categories.	Large quadrats (400 m^2)
Target native shrubs, small trees (non-eucalypt)	Cover (%)	Estimate cover.	Large quadrats (400 m^2)
Shrub recruitment	Presence of seedlings	Assess presence of seedlings.	Large quadrats (400 m^2)
Woody exotics	Cover (%)	Estimate cover.	Large quadrats (400 m^2)
Woody exotic recruitment	Presence of seedlings	Assess presence of seedlings.	Large quadrats (400 m^2)
Understorey	Native species richness and cover	Assess using modified version of Habitat Hectares across the monitoring plot.	Monitoring plot (0.4 ha)
Cover of desirable understory indicator species	Cover (%)	Estimate cover.	Small quadrats (1 m^2)
Cover of undesirable understory indicator species	Cover (%)	Estimate cover.	Small quadrats (1 m^2)
Length of coarse debris	Length (m)	Sum the total length of CWD > 10 cm diameter.	Large quadrats (400 m^2)
Cover of bare ground	Cover (%)	Estimate cover.	Small quadrats (1 m^2)
Cover of soil crust	Cover (%)	Estimate cover.	Small quadrats (1 m^2)
Cover of leaf litter	Cover (%)	Estimate cover.	Small quadrats (1 m^2)
Biomass	Golf ball scores	Assess 18 golf balls (per quadrat) for amount of plant material obscuring ball visibility.	Small quadrats (1 m^2)

Variable	Measurement	Method	Scale of assessment
Fuel hazard	Fuel hazard rating	Fuel hazard rating for different layers of vegetation.	Large quadrats (400 m^2)

2.4.6 Analysis

A hierarchical, Bayesian modelling framework was used to explore a set of six vegetation and ground cover measures (cover of bare ground, litter, biological soil crust, native, exotic, and golf ball scores). Measures were assessed as a function of:

- Wiyn Murrup (areas affected by 'Wiyn Murrup' and areas unaffected by fire, combining both unburnt sites within the Wiyn Murrup footprint and control sites 'Unburnt'), and
- time (before the first fire ('Before'), and one year after the first fire ('After') to ensure comparisons were made in the same season; i.e. autumn).

Data from both monitoring sites affected by Wiyn Murrup (i.e. the You Yangs and Bakers Lane) were combined to ensure there were enough data to allow models to converge. The models can not consider the effects of weed control as only one monitoring site had weed control and it was not applied according to the experimental design. Cover response variables were converted to proportional data (0–1) and followed a beta distribution. Bare ground, biological soil crust, native cover and exotic cover had more zeros than would be expected given the non-zero data and zero-inflation was used. Golf ball score was a number from 0 to 18, reflecting the summed number of 18 golf balls dropped into a small quadrat (Schultz et al. 2017), and the model followed a one-inflated beta distribution.

Small quadrats were clustered within large quadrats, and this structure was reflected in the random effects of each model.

All Bayesian models were fitted using the brms package (Bürkner 2017) in the R statistical program. Uninformative prior distributions were employed for all response variables, and models were fit using the No-U-Turn sampler. Parameters were estimated from four chains of 2000 iterations, 1000 of each chain were used as burn-in periods (total posterior samples = 4000).

We used non-metric multidimensional scaling (NMDS) ordination techniques to examine whether small quadrats (categorised by cover of bare ground, litter, biological soil crust, native, exotic, and golf ball scores) clustered according to the presence or absence of Wiyn Murrup (areas ≥ 80% burnt by Wiyn Murrup ['Wiyn Murrup'], areas within the Wiyn Murrup footprint that remained unburnt ['Unburnt'], and the control areas ['Control']). Unburnt sites are used as temporary counterfactual sites (Duncan and Reich 2016) as it would be inaccurate to assume areas not affected by Wiyn Murrup within the fire footprint would respond in the same manner as Burnt sites. Vectors related to environmental aspects, rainfall (previous 6 months and 12 months) and time since fire (months since fire), and the correlation of each plant and ground cover measure were calculated *a posteriori* to examine if any were strongly associated with Wiyn Murrup, Unburnt and Control sites. These were fitted using the *envfit* function (R vegan package: Oksanen et al. 2016).

Due to the relatively short period of monitoring and the low level of replication within monitoring sites, all other explorations using the full dataset rely on visual interpretations using mean and standard error bar plots with loess smoothers (using the geom_smooth function; based on the raw data) to infer trends over time. In addition, not all quadrats (small or large) within the monitoring sites earmarked for Wiyn Murrup were affected by fire (due to the patchy nature of Wiyn Murrup), resulting in some areas having no fire, fire once, or fire twice, making modelling difficult without oversimplification of the dataset. Where multiple fires have affected a monitoring site (i.e. the You Yangs) we used fire history in the last 12 months to determine the 'Wiyn Murrup' category (≥ 80% burnt for small quadrats and ≥ 40 burnt for large quadrats). The categories Wiyn Murrup, Control and Unburnt were retained in the same manner as for the NMDS analysis.

An assessment of data collected from the Moranghurk site is not included in this report, as they were not affected by Wiyn Murrup prior to the analysis and do not function as adequate control data for any of the other sites due to the geographic isolation from the other monitoring sites (Figure 3). Data relevant to the

Moranghurk monitoring site have been collated and is held by relevant stakeholders. It is anticipated that continued monitoring and the application of Wiyn Murrup at this site will yield data relevant to the KEQs and will be reported on in future.

All analyses were conducted in R version 3.6.3 (R Core Team 2020).

3 Results

3.1 Partner self-assessment

We asked partners to comment on the skills, knowledge and opportunities provided either directly or indirectly as part of the cultural burning component of the Protecting the Victorian Volcanic Plains project (which includes the Wiyn Murrup monitoring program). We also asked participants to identify any challenges faced when engaging with other stakeholders, applying Wiyn Murrup at the monitoring sites or conducting the monitoring, to ensure that these aspects might be improved in future applications of Wiyn Murrup and the next phase of the Wiyn Murrup monitoring program. The responses (paraphrased below) reflect of their views.

Theme 1: Supporting self-determination

- The increased trust between WTOAC and agencies over the program has resulted in WTOAC determining what sites they would like to burn (most evident at Moranghurk a private land site). This independence of decision-making was empowering for WTOAC and was enabled by Corangamite CMA and DEECA partners.
- Agencies supported Wiyn Murrup by supplying a burn plan and burn controller — the Country Fire Authority (CFA) or Forest Fire Management Victoria (FFMVic), DEECA — in line with current laws. While some contention remains about the requirement for this process imposed by agencies (see Theme 3: Challenges), the increased trust between WTOAC and agencies has given WTOAC more autonomy when applying Wiyn Murrup (fewer CFA and FFMVic staff and bushfire mitigation equipment).It has also led to support for Wadawurrung children to be present for Wiyn Murrup to facilitate knowledge exchange within WTOAC and extended families.
- WTOAC contributions towards the design of the monitoring program identified important aspects of GEW for WTOAC members (e.g. desirable and undesirable species). This partnership approach ensured that all partners had a stake in outcomes of the Wiyn Murrup monitoring program. This also facilitated knowledge exchange between WTOAC and other partners, and knowledge brokering within WTOAC.
- WTOAC aspire to continue managing the Wiyn Murrup sites to produce more knowledge, heal Country and gain greater connection to Country. This will require addressing many of the challenges (see Theme 3: Challenges) but if these can be addressed or resolved then the time on Country and capacity to practice culture, facilitated by Wiyn Murrup, will support self-determination.
- Initial plans to explore differences between Wiyn Murrup and other forms of fire management (e.g. planned burning) were quickly abandoned as partners realised that supporting self-determination requires trust. It was decided that validating the outcomes of Wiyn Murrup, or directly comparing or critiquing different approaches, was counter to building trust (i.e. WTOAC should not be expected to prove themselves).

Theme 2: Skills and opportunities

- Building relationships with private landholders (particularly the relationship with the landholder at Moranghurk, which had been established prior to the program) provided WTOAC with more scope to apply Wiyn Murrup to sites that are of particular cultural importance. Ongoing involvement, or co-management, will provide opportunities for WTOAC to practice culture (particularly Wiyn Murrup) in a flexible and adaptive manner and avoid some of the steps required when applying fire on public land.
- This project has helped promote the importance of Wiyn Murrup for healing Country and has (directly or indirectly) led to considerable interest in, and understanding of, WTOAC-led cultural burns (which include Wiyn Murrup) from a range of organisations. With effective communication about the outcomes of cultural burns for other organisations, this interest can result in more demand for WTOAC-led cultural burns.

- The partnership approach to the design and implementation of the monitoring program (bringing together WTOAC, Corangamite CMA, DEECA and ARI) led to greater appreciation of western and Traditional approaches to monitoring and how they can be applied to generate new knowledge which is beneficial to all partners.
- The access to Country, time on Country and support to apply Wiyn Murrup to Country all provided numerous important opportunities and skills for WTOAC. These were essential because pre-European approaches to applying Wiyn Murrup in GEW may not always be appropriate in the new context that GEW currently sits (e.g. weed invasion, human infrastructure and other land uses).These opportunities included:
  - (Re-) learning when and how to apply Wiyn Murrup.
  - Gaining a better understanding of fire behaviour in GEW.
  - Ensuring the passing down of knowledge of Wiyn Murrup to other Wadawurrung people (particularly younger people) while on Country.
- The first application of Wiyn Murrup at the You Yangs monitoring site was attended by Victor Steffensen (an advisor on Aboriginal fire management; Steffensen 2020). This opportunity to hear from Victor was important to give support and confidence to WTOAC and other stakeholders about the outcomes and expectations of Wiyn Murrup. Key messages include:
  - Burning in the beginning is tedious because Country is so unwell.
  - Burning is not primarily for fuel reduction; it is applied to bring back Country's identity.
- The WTOAC Wiyn Murrup and NRM teams have added value to the program not included in the initial project design by:
  - Conducting vegetation monitoring and site assessments
  - Engaging with communication activities and events (videos, newsletters, workshops; see Table 5)
  - Applying targeted weed control
  - Supplying endangered flora for reintroduction into private GEW sites.

Table 5. Communication activities lead or supported by WTOAC.

Partner	Activity type	Title
WTOAC	Video	Ngarrama Dja, Wiyn Dja (To Burn Country, Fire Country)
Corangamite CMA	Video	Understanding Traditional/Cultural Burning
		Connecting to Country Through Fire
		Healing Country and Reconnecting Through Fire
	Newsletter	Caring for Country Team Wiyn Murrup
DEECA	Newsletter	Autumn Cultural Burns on Wadawurrung Country

Theme 3: Challenges

- The interest and enthusiasm for attending Wiyn Murrup for all stakeholders is immense, and there is value in promoting Wiyn Murrup and educating the wider community. However, it is a cultural practice and therefore respect needs to be shown by other agencies who may wish to attend a Wiyn Murrup burn. Therefore, an invitation from those leading the burn should be sought by stakeholders or partners representing other agencies (excluding agency burn controllers if their attendance is

required), and freedom to attend should not be assumed. Effective communication of these concerns has resulted in fewer instances of numerous uninvited agency people attending Wiyn Murrup burns as the program progressed. To resolve this, WTOAC have also willingly been involved in the production and sharing of short videos (that were appropriate for a wider audience) to ensure all interested parties can better understand Wiyn Murrup.

- The capacity to learn from Victor Steffensen during his visit to Country and share knowledge (particularly between Aboriginal people) was hindered by the formal agency expectations of the day. While plans for Victor to attend the first application of Wiyn Murrup at the You Yangs was not known to agency staff, their attendance at the burn disrupted (unintentionally) some of the opportunities for knowledge exchange within WTOAC. Therefore, having some WTOAC-led burns that are more open to agency staff, and others that are closed, could be explored to ensure all stakeholders have their needs met.
- When a window to apply Wiyn Murrup was identified, there was often difficulty in ensuring there are enough resources available at WTOAC to conduct the burn. Therefore, more resources and funding would ensure Country receives Wiyn Murrup at the optimal time to promote healing.
- The short-term funding to support Wiyn Murrup also reduces WTOAC agency over decision making and practice, influences long-term outcomes of Wiyn Murrup, and slows the capacity to generate trust and relationships between partners and stakeholders. More enduring and reliable ongoing support and funding would underpin WTOAC and self-determination, and better support healing of Country .
- There can be a short window to prepare for Wiyn Murrup for it to be most effective. As a result, it can be difficult to navigate government and agency processes when a burn window is identified by WTOAC. While burn controllers are supportive of Wiyn Murrup, the requirement for a burn controller to create and approve a burn plan does not support WTOAC control or agency. Therefore, WTOAC aims to have qualified burn controllers in the Wiyn Murrup team, so that they can write and follow their own burn plans, reducing the need for assistance and resources from CFA or FFMVic.

3.2 Grassy Eucalypt Woodland measures

3.2.1 Fuel

Surface fuel scores changed over time in both the areas affected by Wiyn Murrup and the adjacent control areas (Figure A1.1). No clear reduction in fuel was observed at the You Yangs, relative to the controls (Figure A1.1). At Bakers Lane a strong reduction in fuel was observed, relative to the control quadrat; however, the amount of fuel appeared to recover completely in some quadrats and partially in others (Figure A1.2).

3.2.2 Recruitment

Eucalypt recruitment was relatively low (1–10 recruits / large quadrat) at all sites over the period of monitoring (Table A7). An increase in eucalypt recruitment was observed at Bakers Lane following Wiyn Murrup, but a similar response was observed in the control area, suggesting this change was not due to a post-fire germination event. Eucalypt recruitment was present in low abundances at the You Yangs site. In one quadrat recruitment was relatively high (10–50 individuals) immediately after Wiyn Murrup, but there are no recruitment data from pre-fire monitoring for comparison. In addition, the effect was not retained with subsequent monitoring (Table A7). In the most recent monitoring event at the You Yangs there was no detectable eucalypt recruitment in the site affected by Wiyn Murrup.

Recruitment of native large shrubs and small trees (largely wattles, *Acacia* spp.) was evident at all monitoring sites (except the Wiyn Murrup site at Bakers Lane). However, there was no clear difference between Wiyn Murrup and control sites (Table A7). Cherry Ballart (*Exocarpos cupressiformis*) recruitment occurred (presence-absence data) at the You Yangs site following Wiyn Murrup and was not observed in the control site.

Recruitment of woody weeds was most obvious for Galenia (*Aizoon pubescens*) recruitment at both Bakers Lane and the You Yangs and for Boneseed, which occurred only at the You Yangs. Galenia recruitment

occurred only in control areas (i.e. not observed in the Wiyn Murrup footprint; Table A7), while Boneseed recruitment was observed in the Wiyn Murrup footprint both before and after fire, and only more recently in the control area (Table A7).

3.2.3 Understorey vegetation and ground cover

Wiyn Murrup resulted in an increase in bare ground cover (marginal difference; Figures 6, A2.3, Table A6) and decrease in grassy biomass (indicated by higher golf ball scores) one year after fire (Figures 6, A3, Table A6). Litter, biological soil crust, native cover and exotic cover did not change in response to Wiyn Murrup one year after fire (Figures 6, A2.4, A2.5, Table A6). These changes are mirrored in the understorey assessments of vegetation cover and species richness for both the You Yangs (Figures A5.1, A5.2) and Bakers Lane (Figures A5.3, A5.4), where no obvious changes in native species richness or cover have emerged over the first phase of monitoring.

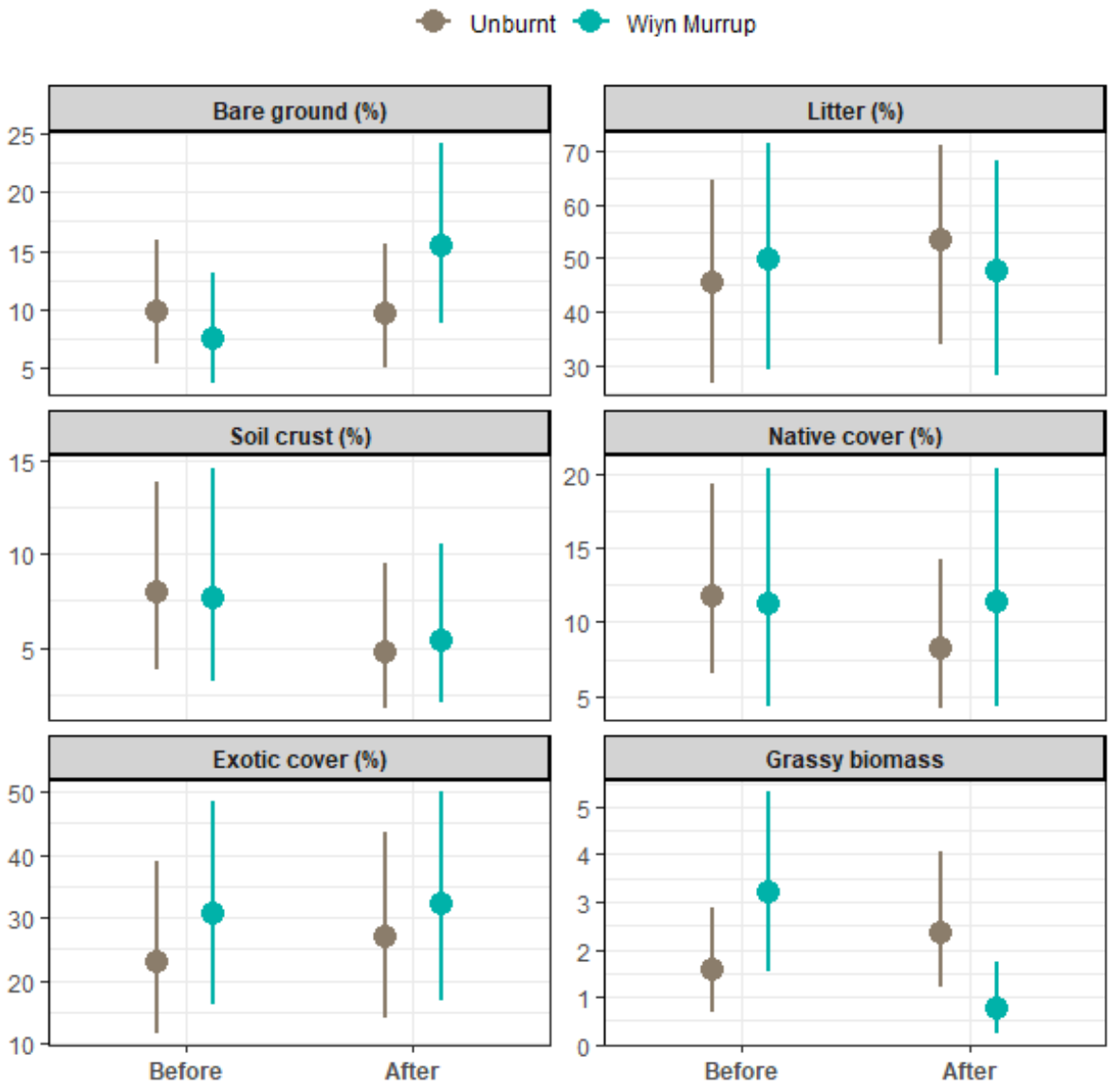

Figure 6. Model estimates for responses before and one year after Wiyn Murrup. 'Grassy biomass' is the complement of golf ball scores. Error bars represent 95% credible intervals for estimates.

Cover of indicator species (both desirable and undesirable) exhibited variable responses over time (Figures A2.1, A2,2, 7, 8). Boneseed cover was largely absent from the control quadrats at the You Yangs site, making inferences about the capacity of Wiyn Murrup to control Boneseed difficult (Figure 7). A large reduction in Boneseed cover was observed in an unburnt quadrat within the Wiyn Murrup footprint, but was not observed in Wiyn Murrup or control quadrats (Figure 7). Annual Veldt-grass cover declined relative to the control site at the You Yangs prior to the second implementation of Wiyn Murrup (Figure 8), but appears to have recovered by the end of the monitoring program.

Composition, which was informed by measures of plant cover (differentiated by origin), ground cover and biomass, suggests no clear separation in response to Wiyn Murrup (Figure 9). Time since Wiyn Murrup and rainfall had negligible explanatory power (Figure 9).

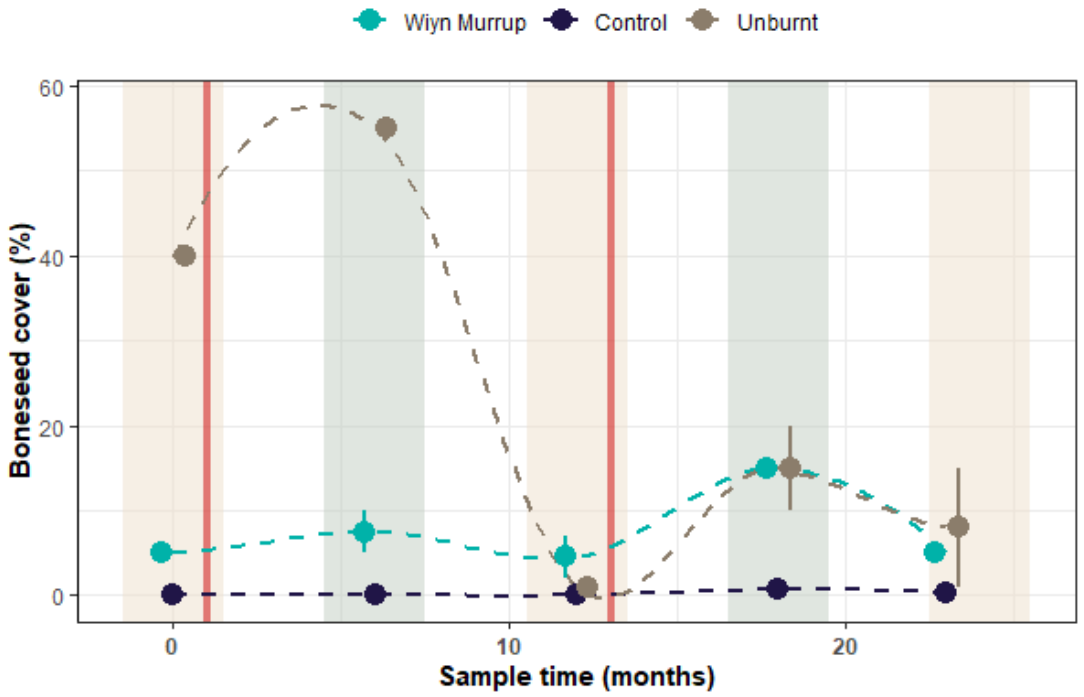

Figure 7. Mean boneseed cover over time at the You Yangs. Data are from large quadrats.

Vertical lines (orange) indicate timing of Wiyn Murrup. Shaded vertical bars indicate autumn (brown) and spring (green).

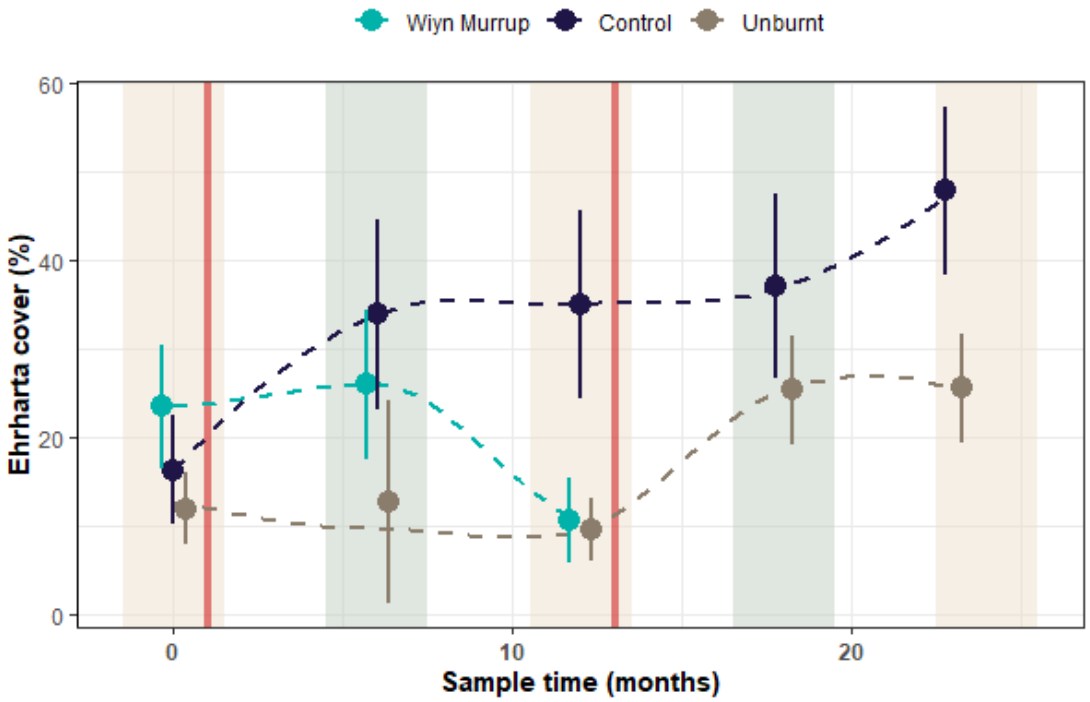

Figure 8. Mean annual Veldt-grass (*Ehrharta longiflora*) cover over time at the You Yangs. Data are for small quadrats.

Vertical lines (orange) indicate timing of Wiyn Murrup. Shaded vertical bars indicate autumn (brown) and spring (green).

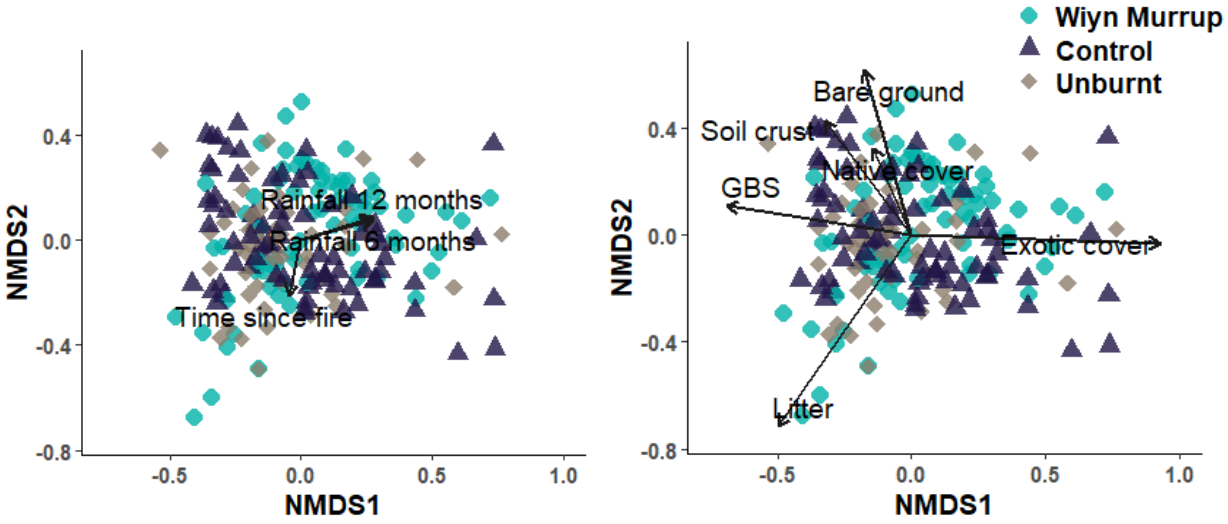

Figure 9. Non-metric multidimensional scaling ordination of simplified plant composition for each small quadrat across Bakers Lane and the You Yangs for monitoring in spring (2021-2022).

Arrows represent the post-hoc projection of environmental vectors (left) and plant and ground cover (right). Stress = 0.18.

4 Discussion

Many decades after being displaced from their ancestral lands, the Wadawurrung people (here represented by WTOAC) have been supported by this project to reintroduce Wiyn Murrup at the You Yangs and Moranghurk (Wiyn Murrup had been applied at Bakers Lane in the recent past). Time on Country to attend meetings, conduct monitoring, and apply Wiyn Murrup, has improved WTOAC's understanding of when to apply Wiyn Murrup (i.e. the burn window), how the ecosystem responds to Wiyn Murrup, and what additional land management might be needed to heal Country in the long-term. In addition, trust, active listening and effective relationships by and with agency partners have contributed to WTOAC being able to determine where, when and how they apply Wiyn Murrup. However, some inherent challenges remain, particularly around meaningful agency for WTOAC, and require further understanding to ensure the best outcomes for Wadawurrung people and the environment.

Wiyn Murrup led to an increase in bare ground cover and decrease in grassy biomass, and these changes persisted for one year after fire. Most other attributes were dynamic over time, but it was difficult to determine whether they were directly impacted by Wiyn Murrup. However, these patterns still offered important opportunities to gain a better understanding about how Country changes immediately after Wiyn Murrup and how it recovers in the period following Wiyn Murrup.

4.1 Partner self-assessment

Many of the gains made regarding the monitoring program and the implementation of Wiyn Murrup centre on increased trust, active listening and building relationships. While challenges remain (typically due to agency expectations, processes, terms and schedules), support for the monitoring program and the application of Wiyn Murrup is strong. Partners remain keen to continue the monitoring program to reduce or eliminate disempowerment and increase knowledge of the cultural and ecological outcomes of Wiyn Murrup on GEW for all stakeholders.

4.1.1 Creating reciprocity and trust

Partners emphasised the importance of establishing trust and maintaining strong relationships amongst partners, and with the broader community. Successful collaborations are often underpinned by robust social connections between individuals (Bodin 2017). We recognise there is no quick solution to developing effective interpersonal or institutional relationships. Relationships take time to develop and are founded on active and careful listening, trust, reciprocity and familiarity over many months and years (Rawluk et al. 2023). We feel a foundation of trust and reciprocity has been laid in the first phase of this project, but willingness to understand and a capacity to listen will need to be continued.

4.1.2 Working on Country

Access to Country and time spent applying Wiyn Murrup allowed WTOAC to acquire essential skills, better understand fire behaviour in GEW, and pass on knowledge. Likewise, non-Aboriginal partners also gained a better appreciation of the importance of Wiyn Murrup for cultural heritage and the environment, and these partners have become stronger advocates for self-determination of Aboriginal people. All of these benefits come about due to time spent on Country. While the monitoring program requires time on Country to collect data, additional time on Country was supported by meetings, training, and an expert visit from Victor Steffensen. In each instance these provided additional opportunities to develop skills and share knowledge with partners. WTOAC members also identified culture as a key driver in their land management aspirations, and that time on Country was essential for this. This is a sentiment shared by other Aboriginal groups involved in land management (e.g. McKemey et al. 2019, 2021).

4.1.3 Disempowerment and agency

All of the challenges faced by WTOAC occurred when planning and implementing Wiyn Murrup. They related to either people (often non-Aboriginal people) attending cultural practices when not invited, or systemic issues related to government or agency (i.e. requirements around burn plans etc.). Challenges navigating government or agency requirements when conducting land management (often using cultural practices like

fire) have been previously reported by Aboriginal people (Neale et al. 2019; Rawluk et al. 2023). Identifying these challenges presents an opportunity to explore new ways of supporting self-determination and governing Country (Rawluk et al. 2023).

With hindsight we observed that many of the approaches to the research questions were dominated by the western view of science. While attempts to include Traditional knowledge into the monitoring program were sought and included, the program didn't conceive of the idea of asking questions related to the impacts of the monitoring program on culture and the pursuit of self-determination of Aboriginal people in the design phase. While these were identified early in the program, and are pursued in this report, this is an important learning from the first phase of the monitoring program. In many cases, exploring research questions related to cultural practices should spend more time considering the *how* instead of jumping straight into the *what* (i.e. to focus initially on how to determine what kinds of questions to ask, and decide on what types of data to collect; Smith et al. 2021; Rawluk et al. 2023). This will enable the appropriate design of useful and impactful monitoring objectives and outputs (i.e. the *what*).

4.2 Grassy Eucalypt Woodland measures

Participants conducting the monitoring were primarily interested to learn how Wiyn Murrup can be used to heal Country and improve GEW condition. The first phase was to use Wiyn Murrup to 'clean up' the sites so that future fires could be used more effectively. The next phase was to reduce grassy biomass and leaf litter to promote growth and germination of native species and to reinvigorate the productivity of the site. It is these early phases which are being captured by the monitoring dataset presented here. Wiyn Murrup resulted in an increase in bare ground cover and decrease in grassy biomass that persisted for at least one year after fire. This finding was not surprising as fire consumes plant tissue which reduces biomass and opens up a grassy understorey to expose bare ground (McIntyre et al. 2015). It is uncertain, however, whether the reduction in biomass is more prominent at Bakers Lane, which has more grassy cover and biomass, or if the increase in bare ground is more prominent at the You Yangs where grass cover is sparser, as data from both sites were combined to ensure there was enough data to conduct the analysis. It was expected that leaf litter cover would decrease, complementing the increase in bare ground cover within the first phase of the monitoring program, but this did not occur. A similar response was observed by McKemey et al. (2019) when they assessed the outcomes of cultural burning on Echidna habitat in the Banbai Nation in northern New South Wales. We suspect that either the cool-burning approach to Wiyn Murrup is both consuming and producing leaf litter as live plant tissue is singed, detached and relocated to the ground layer, or Wiyn Murrup is not affecting leaf litter at ground level, but instead jumping over the inter-tussock gaps where leaf litter tends to accumulate in grassy ecosystems.

Grazing (by both native and exotic herbivores), rainfall and fire all influence eucalypt recruitment in woodlands (Rumpff et al. 2011). In some cases, the combination of land-use change along with favourable climatic conditions can cause thickets of eucalypt regeneration to emerge (Rumpff et al. 2011). The increases in Eucalypt recruitment we observed are more likely influenced by the higher-than-average rainfall over the monitoring period as this affects both the control and Wiyn Murrup monitoring sites. Where evidence of recruitment has disappeared (at the You Yangs), we are not certain if this represents mortality, or growth into an older age-cohort not classified as recruitment. Recruitment of Cherry Ballart (a root hemiparasite) was observed following Wiyn Murrup, but the influence of Wiyn Murrup on this event is uncertain due to rarity of this event across the network of monitoring quadrats and as data is only presence or absence (i.e. not abundance data). Recruitment of the exotic woody shrub Boneseed occurred more commonly in areas affected by Wiyn Murrup but few adults (and no recruits) were observed in the control area. This again makes inferring the role of Wiyn Murrup on this event difficult. Although the data are not yet strong, it seems likely that Wiyn Murrup causes an increase in Boneseed germination from its seed bank. This is not necessarily a bad thing when viewed over the long term, as expressing the seed bank can be the first stage of control, if followed by control of resulting plants before they set seed.

While in some cases fire can have a profound impact on the recovery of native species, or reducing the cover of weeds, this is often in relation to long-established fire regimes (Lunt et al. 2012), rather than the reinvigoration of fire in the short-term. Therefore, it is premature to look for the longer-term aspirations related to GEW in the current program. From the data so far, it appears that the cover of dominant

understorey weeds at each site (at Bakers Lane, exotic perennial grasses, mainly Phalaris; at the You Yangs, exotic annual grasses, mainly Annual Veldt-grass) were maintained over the monitoring program, and this will likely prevent any observed improvement in native species response in the short-term. Native species may not be able to recolonise areas effectively until weed cover is reduced below a certain threshold (Gooden et al. 2009). There was one obvious reduction in Boneseed cover after Wiyn Murrup was applied, but this occurred in an area that did not receive burning, and therefore is much more likely attributable to the additional Boneseed control activities (hand pulling of adults and juveniles) undertaken at the You Yang site during this time. The responses of the dominant weeds after Wiyn Murrup has prompted discussions about how Wiyn Murrup can be used more strategically to affect these threats. This is important because the threat posed by weeds on Inland Country (which includes GEW) is significant and is categorised as 'high threat' in the Wadawurrung Country Plan (WTOAC 2020). This might require modifying the timing of Wiyn Murrup (e.g. to affect annual grasses before they produce seed; Sweet et al. 2008), or strategically applying weed control so that the impact of Wiyn Murrup is more effective on reducing cover and regeneration events (Emery et al. 2013).

4.3 Two ways of knowing

Initially, the partnership between WTOAC and Corangamite CMA was for the delivery of three WTOAC-led Wiyn Murrup burns. However, the partnership and trust between organisations quickly grew, which resulted in WTOAC:

- determining which sites to burn based on condition, cultural significant and landscape connection,
- co-authoring the monitoring framework report (Farmilo et al. 2021),
- choosing the indicator species as part of the monitoring,
- co-conducting the monitoring, and
- supporting a range of communication activities to share knowledge about Wiyn Murrup with the community.

This early progress in the project meant that partners representing both Traditional and western approaches to ecological management felt safe to share knowledge, understanding that it would help heal Country and improve GEW condition. In particular, WTOAC discussed their experience and learning about Wiyn Murrup, recorded traditional knowledge related to GEW, learnt through participation about the western approach to fire ecology, collected data, and discussed the research within their organisation. The western scientists learnt from WTOAC, reviewed the scientific literature, co-developed the monitoring framework, collected and analysed data, and disseminated results. This cross-cultural approach to monitoring the outcomes of Wiyn Murrup will inform adaptive management. Burning the landscape for particular values is complex because numerous drivers of vegetation are happening simultaneously. However, with time on Country and experience managing land to improve the health of Country, it is hoped that burning can become a common practice based on logic and intuition.

4.4 Recommendations and further work

Twelve recommendations and opportunities for future work and programs are identified.

Wiyn Murrup

1. Managing who attends Wiyn Murrup burns requires careful consideration. Ultimately, those outside WTOAC should seek an invitation to attend the burn. In some cases, it may not be appropriate for non-Aboriginal people to attend particular burns, for cultural reasons. Likewise, it is important that WTOAC manages these invitations strategically so that non-Aboriginal agency staff and researchers get an opportunity to attend Wiyn Murrup burns to facilitate inter-agency knowledge exchange and champion the role of Wiyn Murrup in managing GEW. This sentiment also applies to meetings with experts related to cultural activities (e.g. meetings with Aboriginal fire experts) on Country.
2. Continuing to support engagement between WTOAC Wiyn Murrup team and private landholders can provide more options for WTOAC to apply Wiyn Murrup to improve ecological and cultural outcomes.

Engaging directly with private landholders can help avoid government or agency requirements that surrounds burning on public land until greater decision-making power is placed in the hands of WTOAC.

3. Support (funding or otherwise) should be given to WTOAC to increase their capacity to plan their own burns (particularly Wiyn Murrup), to navigate government or agency requirements, and to allow more flexibility to conduct Wiyn Murrup when the burn window is most appropriate.
4. It is recommended that Wiyn Murrup and associated monitoring should continue if funding (likely from the Commonwealth Government) can be secured.

Monitoring programs

5. The foundation of trust and reciprocity established in the first phase of this project needs to be facilitated and continued, and all partners (new or established) should understand the importance of active listening and time on Country in supporting these relationships.
6. Future programs should be less prescriptive with outputs to allow WTOAC to assess sites on a case-by-case basis and determine if and when Country is ready to have fire applied, or if other traditional land management practices would be more appropriate.
7. The current monitoring program should plan for future. While long-term monitoring is important for generating data that can inform the ecological outcome of Wiyn Murrup, there may come a point where maintaining control sites (i.e. areas where Wiyn Murrup is excluded) could be detrimental to the health of Country (e.g. weed reinvasion). Therefore, there may be a point where control sites are abandoned to ensure Wiyn Murrup can be applied across the entire site. If control sites are abandoned in the future, monitoring data will still be useful for evaluating the outcomes of Wiyn Murrup, and should be continued.
8. Currently, benchmarks against which GEW measures are compared are determined largely from western science (e.g. EVC benchmarks and scientific literature). As more knowledge about the desires of WTOAC for particular measures are known, these should be incorporated into the monitoring framework.

Monitoring approach

9. Future monitoring should aim to add new sites (perhaps with a native-dominated understorey) into the monitoring program. This would gain further insights into the role of Wiyn Murrup in healing Country and how this trajectory changes with woodlands with a different starting condition in the understorey.
10. Recent curation of the dataset and consideration of future uses of the monitoring has identified some variations on the current methods to capture more detailed information on specific areas of interest (i.e. especially recruitment).
11. Measuring the recruitment of native shrubs and small trees, or woody weeds, could involve quantifying abundance (as estimates, abundance categories or counts) rather than the current approach of determining presence–absence of recruitment. This would enable more clarity about the role of Wiyn Murrup on recruitment of these important values (native shrubs) and threats (woody weeds).
12. More consistency in the framing of tree-canopy photographs would ensure greater accuracy of estimates of canopy cover and allow finer-scale change in canopy cover to be detected. This could be done by referring to previous photographs and using these to frame a canopy photo in line with obvious features (e.g. large limbs).

The first phase of this monitoring program has established positive relationships between partners that is built on trust, and has generated a baseline of understanding about the immediate ecological response to Wiyn Murrup. However, there is much more work to do to support Aboriginal people to practice culture in a way that is safe, supported and which results in healthy Country for all Australians to enjoy.

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Appendices

Appendix 1 – Fuel hazard

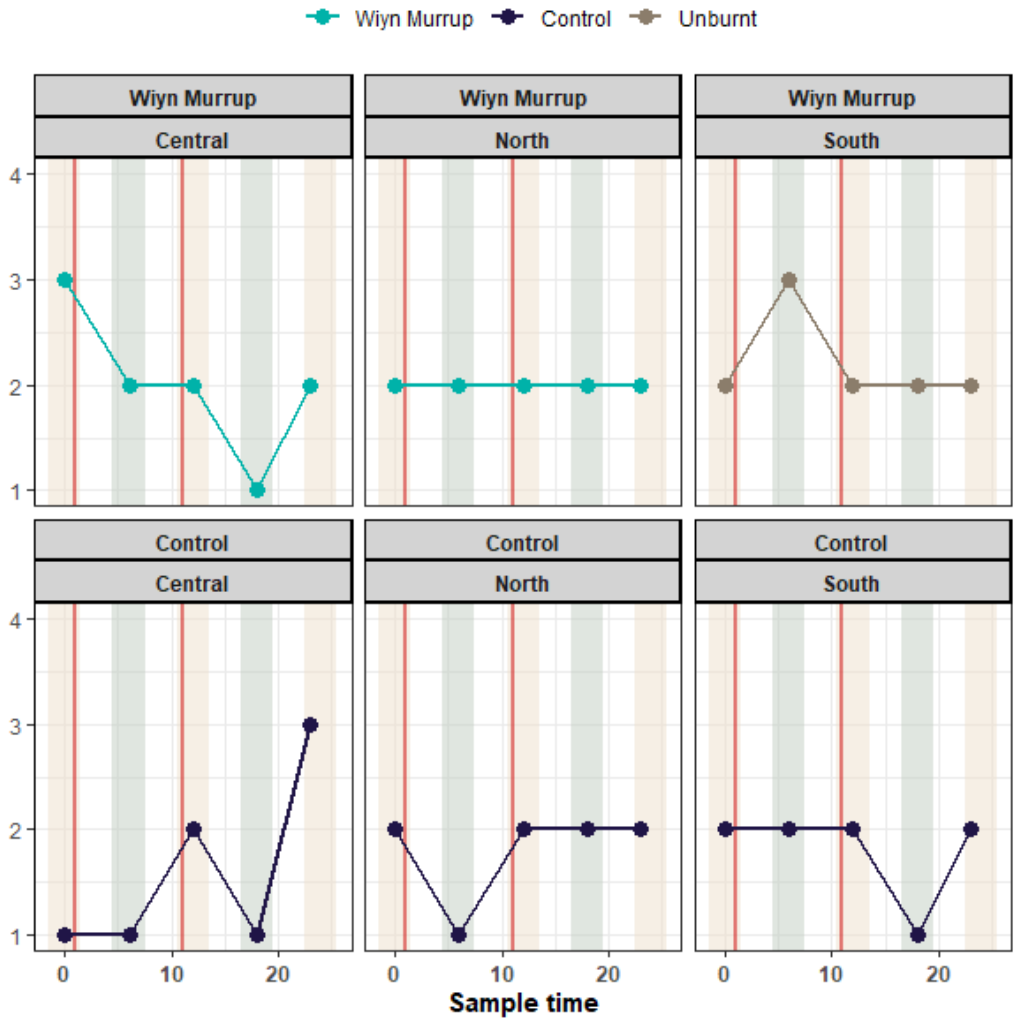

Figure A1.1 Surface fuel categories (1 – low, 2 – moderate, 3 – high, 4 – very high) over time (months) for each large quadrat at the You Yangs.

Vertical lines indicate timing of Wiyn Murrup (not relevant to Control site). The second burn (average burn cover 15%) did not affect large quadrats to the same extent as the first burn (average burn cover 37%). The unburnt quadrat received only 10% burn cover so was considered unburnt in this case. Shaded vertical bars indicate autumn (brown) and spring (green).

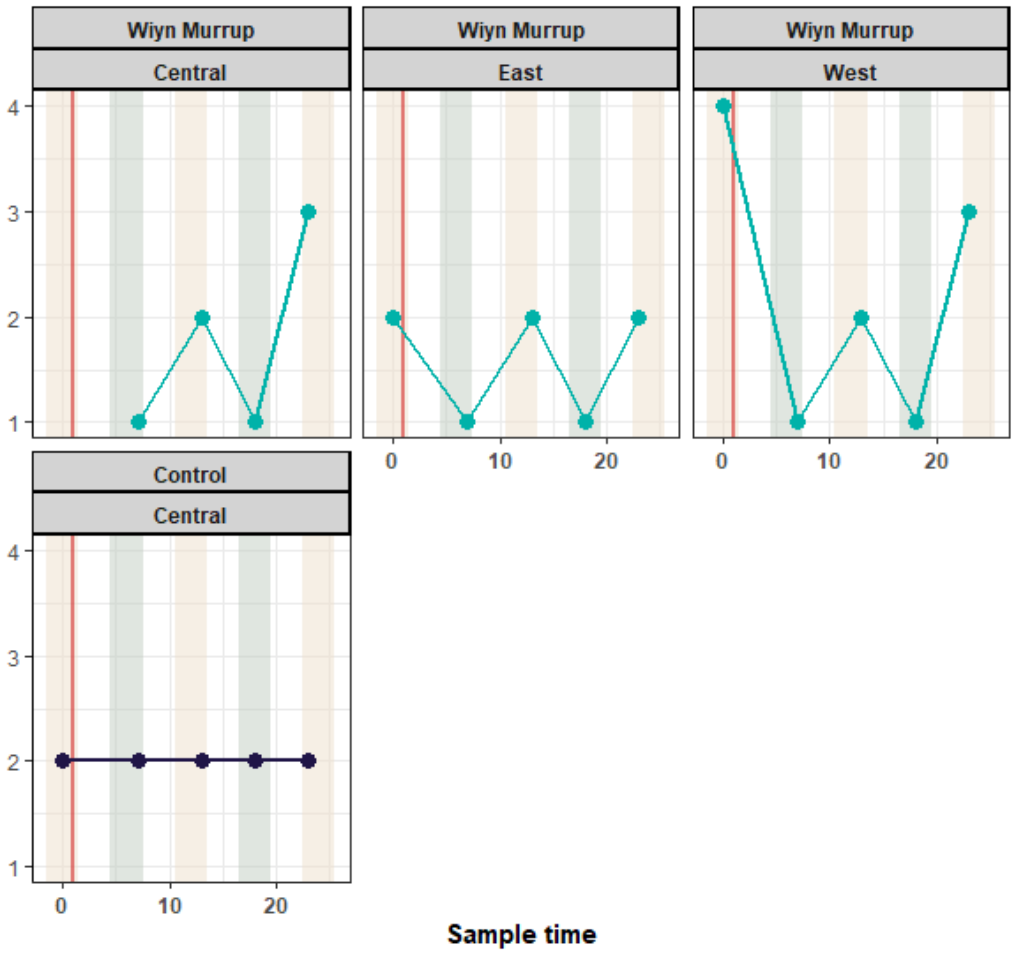

Figure A1.2. Surface fuel categories (1 – low, 2 – moderate, 3 – high, 4 – very high) over time (months) for each large quadrat at Bakers Lane.

Vertical lines indicate timing of Wiyn Murrup (not relevant to Control site). On average 94% of quadrats were affected by Wiyn Murrup. Pre-burn data is missing for the Central quadrat. Shaded vertical bars indicate autumn (brown) and spring (green).

Appendix 2 – Cover changes

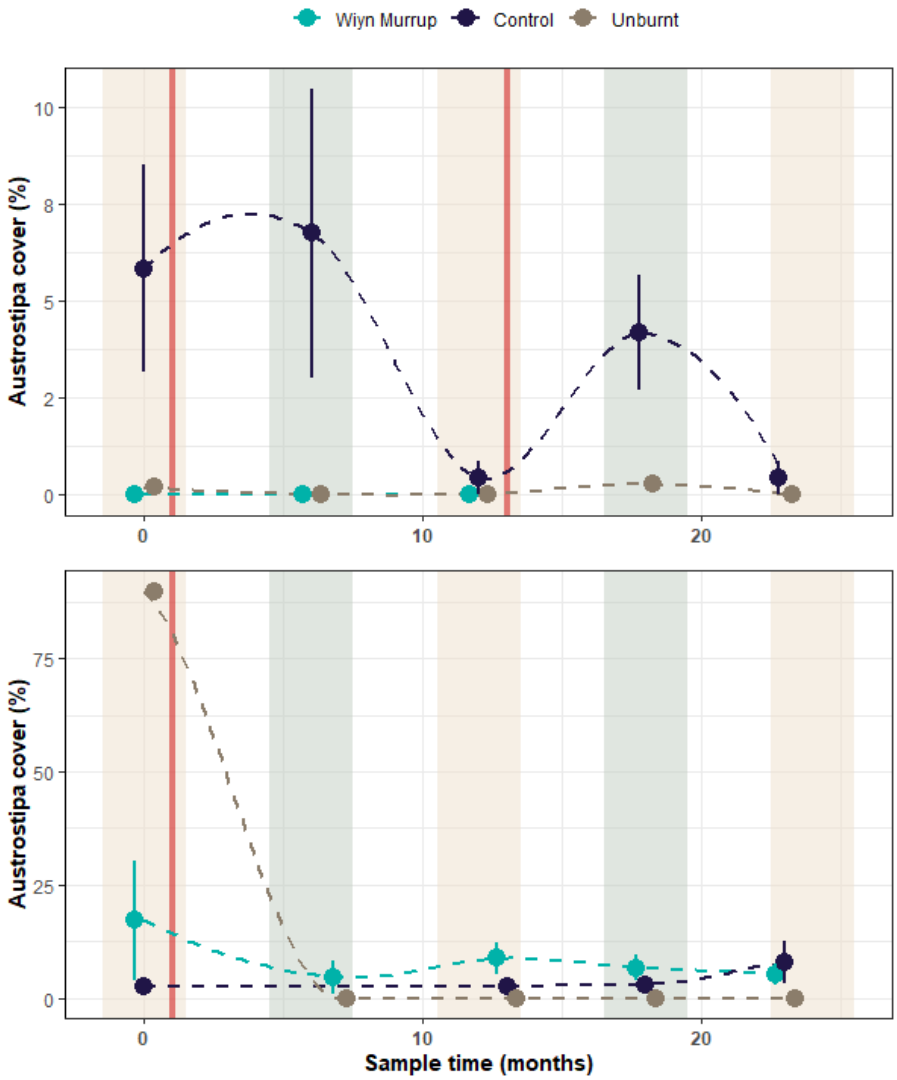

Figure A2.1 *Austrostipa* spp. cover over the monitoring period for You Yangs (top) and Bakers Lane (bottom). Data from small quadrats. Note the large difference in range on the y-axis.

Vertical lines (orange) indicate timing of Wiyn Murrup. Shaded vertical bars indicate autumn (brown) and spring (green).

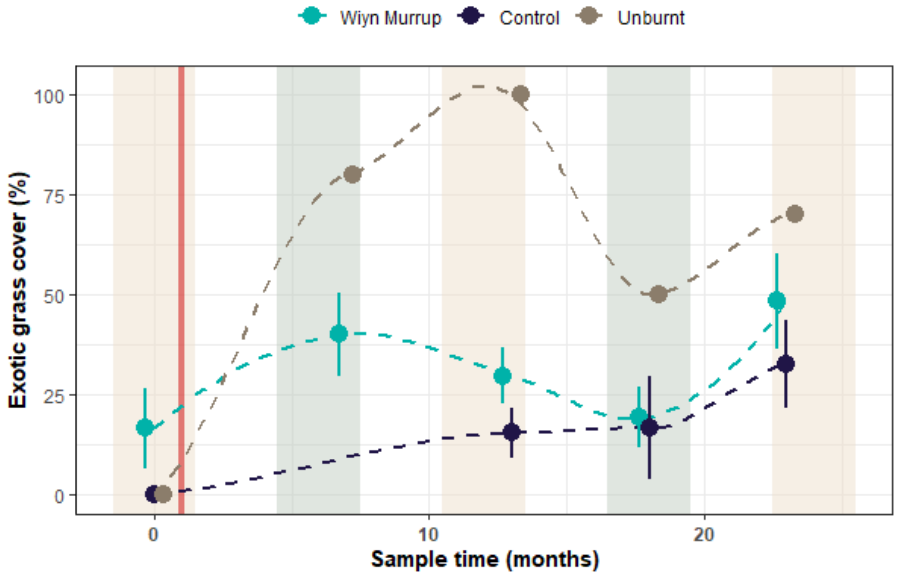

Figure A2.2. Exotic grass cover over the monitoring period for Bakers Lane. Data from small quadrats.

Vertical lines (orange) indicate timing of Wiyn Murrup. Shaded vertical bars indicate autumn (brown) and spring (green).

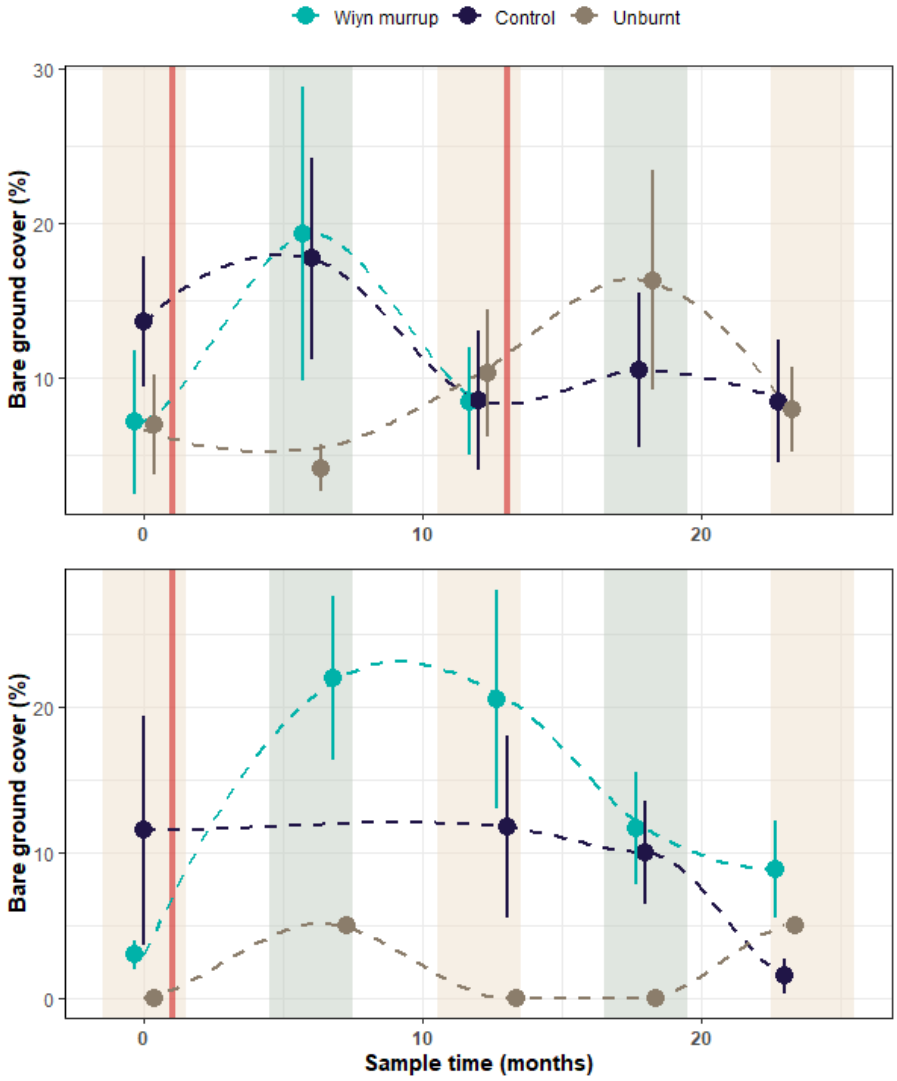

Figure A2.3. Bare ground cover over the monitoring period for You Yangs (top) and Bakers Lane (bottom). Data from small quadrats.

Vertical lines (orange) indicate timing of Wiyn Murrup. Shaded vertical bars indicate autumn (brown) and spring (green).

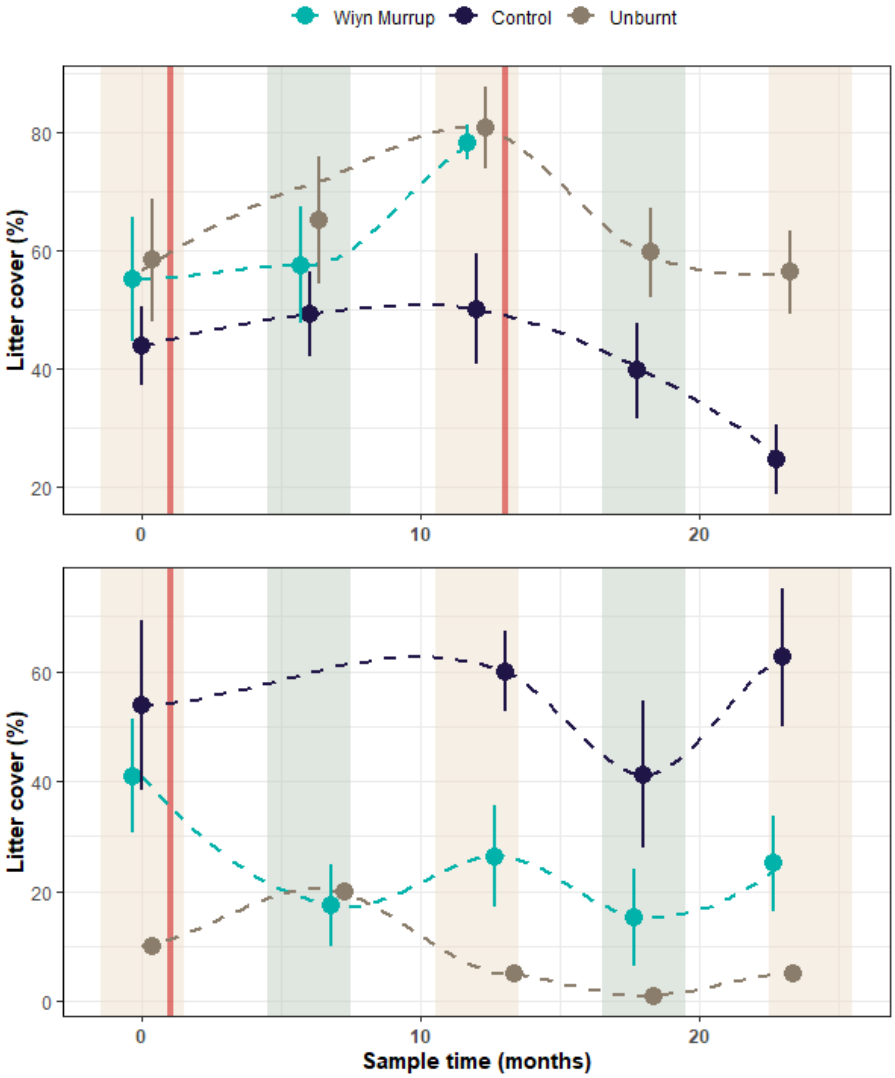

Figure A2.4. Litter cover over the monitoring period for You Yangs (top) and Bakers Lane (bottom). Data from small quadrats.

Vertical lines (orange) indicate timing of Wiyn Murrup. Shaded vertical bars indicate autumn (brown) and spring (green).

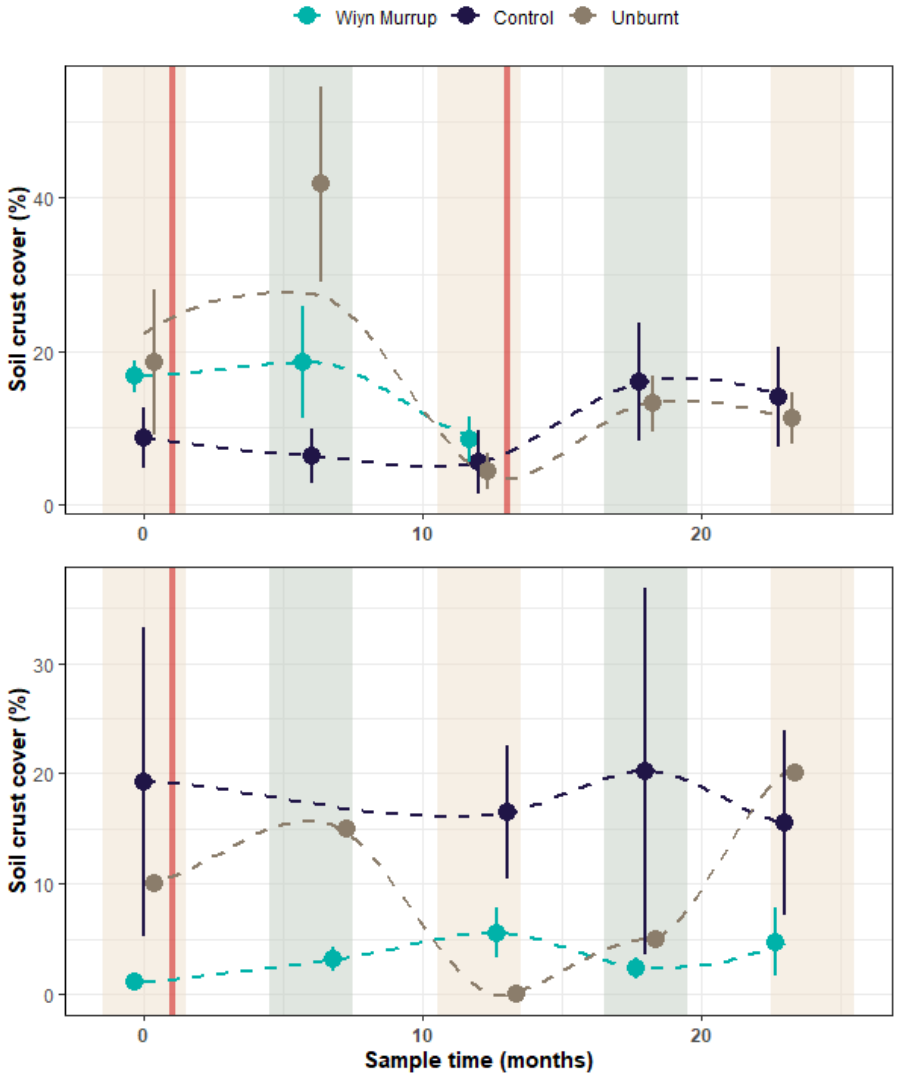

Figure A2.5. Soil crust cover over the monitoring period for You Yangs (top) and Bakers Lane (bottom). Data from small quadrats.

Vertical lines (orange) indicate timing of Wiyn Murrup. Shaded vertical bars indicate autumn (brown) and spring (green).

Appendix 3 – Grassy biomass

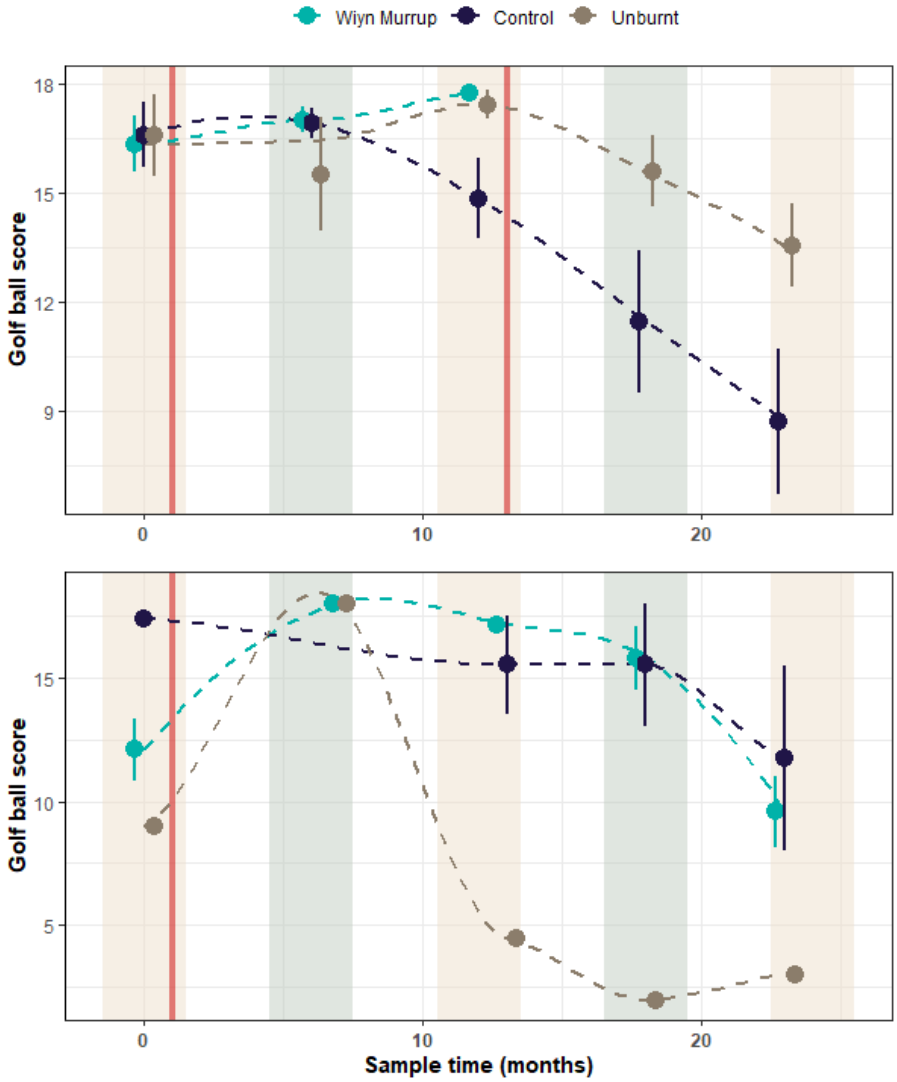

Figure A3. Golf ball scores (high scores indicate low grassy biomass) over the sampling period (months) You Yangs (top) and Bakers Lane (bottom). Data from small quadrats.

Vertical lines (orange) indicate timing of Wiyn Murrup. Shaded vertical bars indicate autumn (brown) and spring (green).

Appendix 4 – Desirable and undesirable species

Table A4. List of desirable and undesirable species identified during monitoring and the reasons for inclusion.

Desirability	Monitoring site	Species name	Common name	Reason for inclusion (Traditional)	Reason for inclusion (ecology)
Desirable	Bakers Lane	*Acacia pycnantha*	Golden Wattle	Food, spears, tools	Habitat
		Astroloma humifusum	Cranberry Heath		Rare on site
		Austrostipa spp.	Spear-grasses	Fibre	Habitat
		Convolvulus spp.	Bindweeds	Food	Uncommon
		Dianella spp.	Flax-lilies	Food	Uncommon, habitat
		Thelymitra spp.	Sun orchids		Rare on site
	You Yangs	*Austrostipa* spp.	Spear-grasses	Fibre	Rare on site
		Carpobrotus modestus	Pigface, Karkalla	Food	Habitat, aesthetic, native
		Cheilanthes austrotenuifolia	Rock fern		Native
		Dichondra repens	Kidney weed		Rare on site
		Einadia nutans	Chenopod		Habitat
		Exocarpos cupressiformis	Cherry Ballart		Rare on site
		Pterostylis spp.	Greenhood orchids		Rare on site
		Rytidosperma spp.	Wallaby-grasses	Food, fibre	Habitat
Undesirable	Bakers Lane	*Agrostis capillaris*	Brown-top Bent	Introduced	Competition
		Aizoon spp.	Galenia, Carpet-weeds	Aesthetic	Competition
		Disa bracteata	South African Weed Orchid		Emerging weed
		Introduced grasses		Introduced	Competition
		Phalaris aquatica	Phalaris		Fire hazard
	You Yangs	*Aizoon* spp.	Galenia, Carpet-weeds	Introduced, obscuring cultural sites, aesthetic	Competition, allelopathy
		Asparagus asparagoides	Bridal Creeper	introduced, obscuring cultural sites, aesthetic	Competition, allelopathy
		Chrysanthemoides monilifera	Boneseed	Restricting access, aesthetic, obscuring cultural sites	Competition, fire hazard
		Ehrharta longiflora	Annual Veldt-grass	introduced, aesthetic, Obscure cultural sites	Competition, allelopathy, fire hazard
		Lycium ferocissimum	African Boxthorn	Introduced, aesthetic	Competition

Appendix 5 – Monitoring site understorey

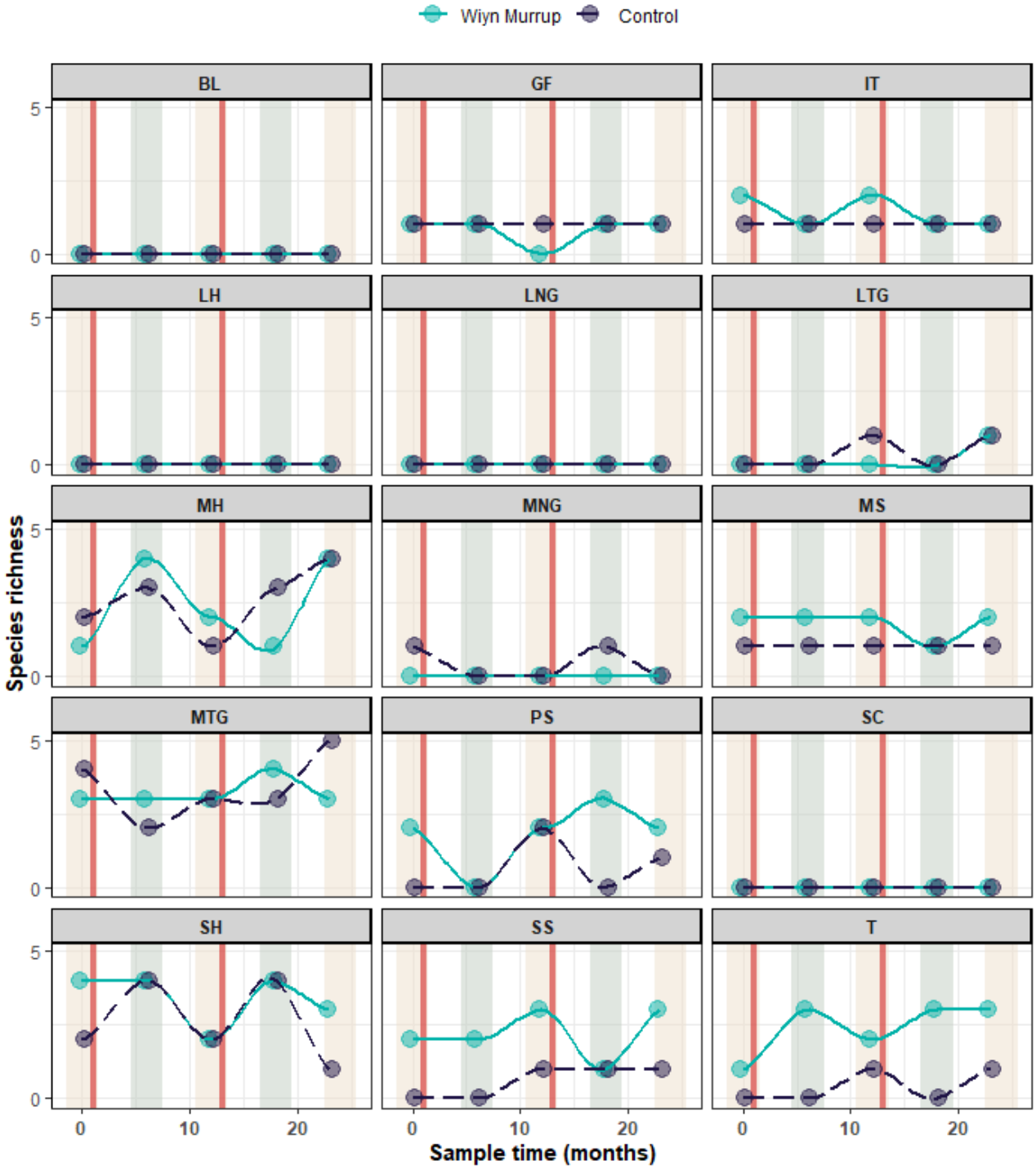

Figure A5.1. Native species richness differentiated into life forms at the You Yangs monitoring site.

(BL- bryophytes/lichen; GF – ground fern; IT – immature tree; LH – large herb; LNG – large non-tufted graminoid; LTG – large tufted graminoid; MH – medium herb; MNG – medium non-tufted graminoid; MS – medium shrub; MTG – medium tufted graminoid; PS – prostrate shrub; SC – scrambler/climber; SH – small herb; SS – small shrub; T – tree). Vertical lines (orange) indicate timing of Wiyn Murrup Shaded vertical bars indicate autumn (brown) and spring (green).

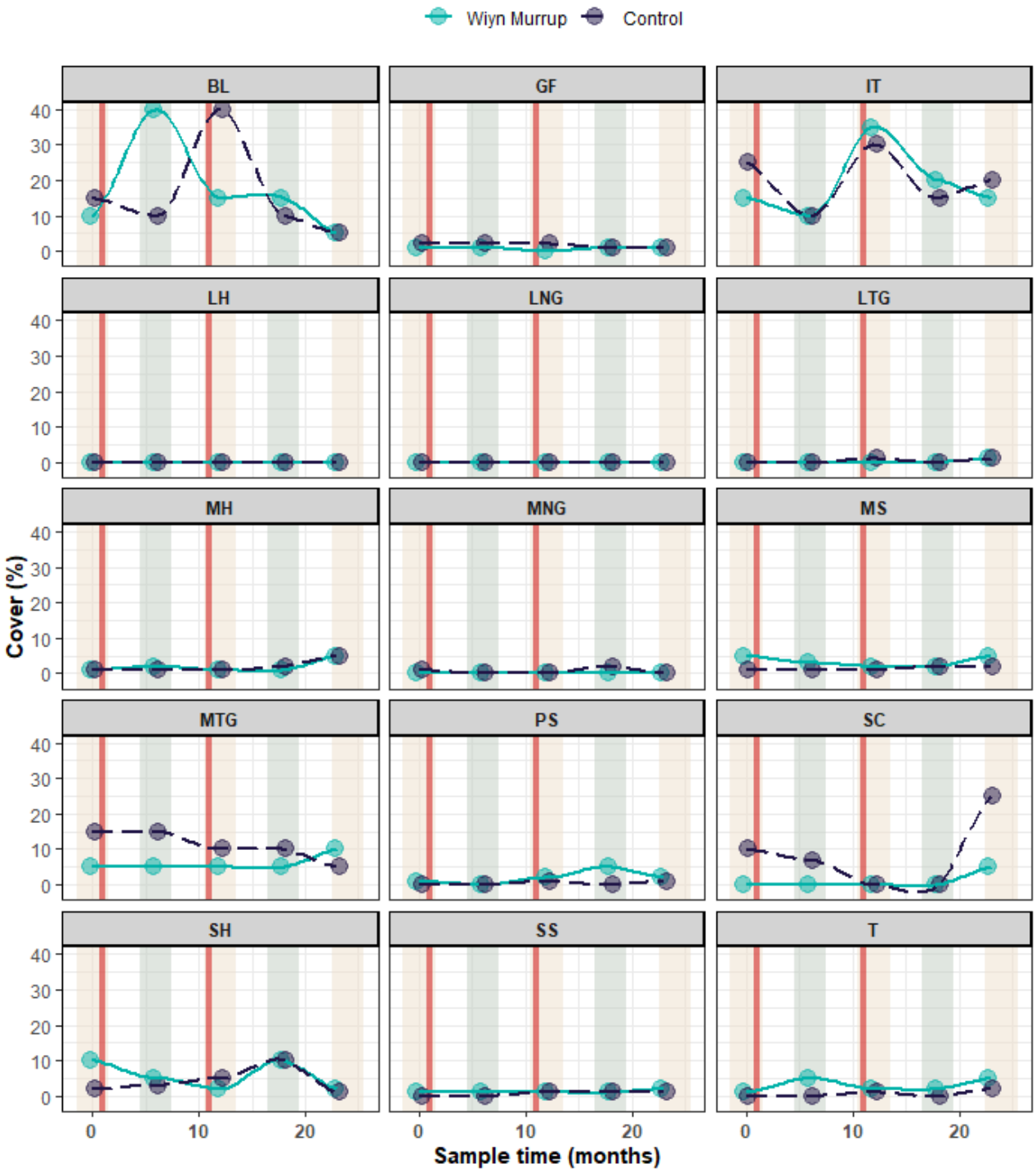

Figure A5.2. Native species cover differentiated into life forms at the You Yangs monitoring site.

(BL- bryophytes/lichen; GF – ground fern; IT – immature tree; LH – large herb; LNG – large non-tufted graminoid; LTG – large tufted graminoid; MH – medium herb; MNG – medium non-tufted graminoid; MS – medium shrub; MTG – medium tufted graminoid; PS – prostrate shrub; SC – scrambler/climber; SH – small herb; SS – small shrub; T – tree). Vertical lines (orange) indicate timing of Wiyn Murrup Shaded vertical bars indicate autumn (brown) and spring (green).

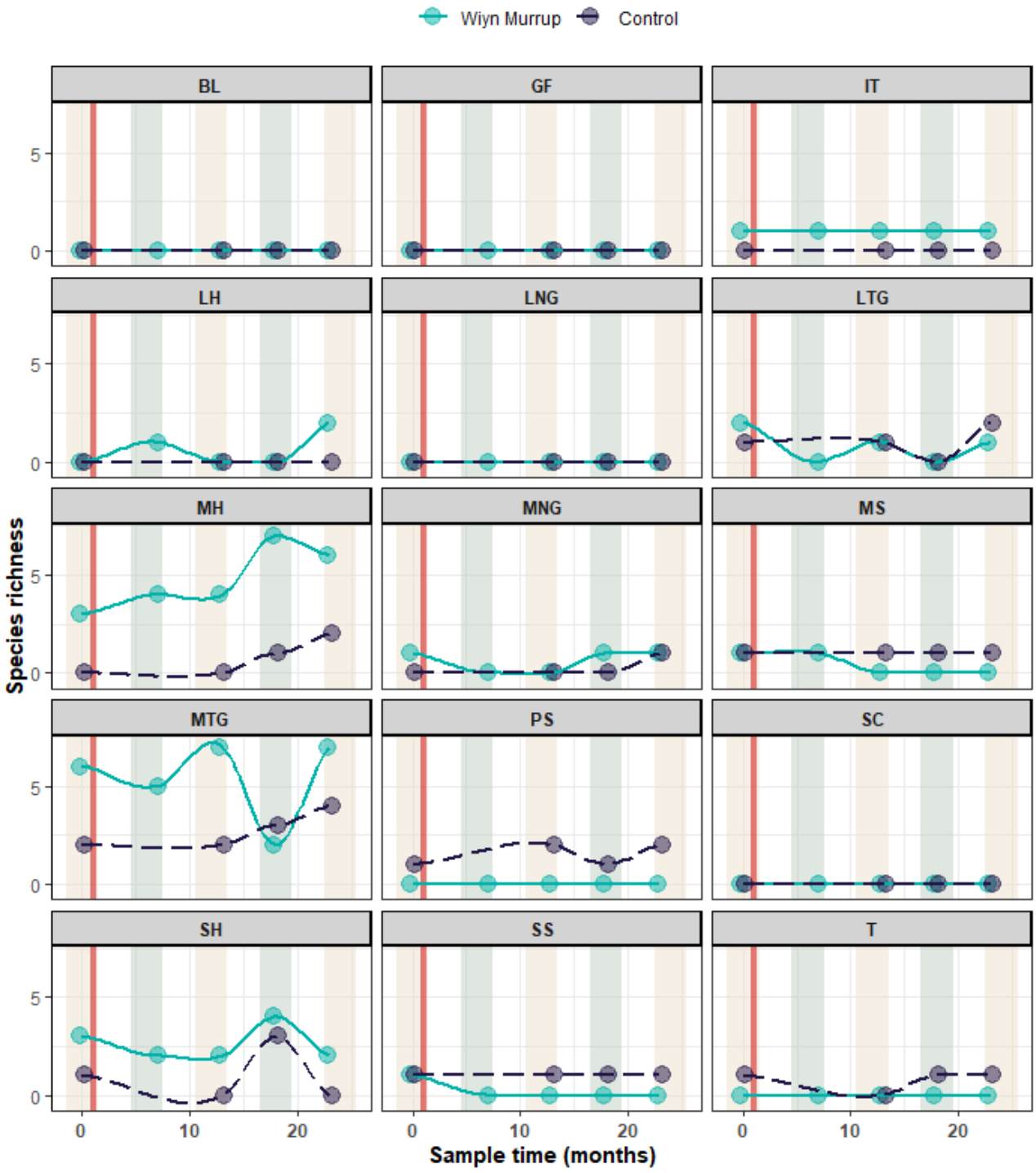

Figure A5.3. Native species richness differentiated into life forms at the Bakers Lane monitoring site.

(BL- bryophytes/lichen; GF – ground fern; IT – immature tree; LH – large herb; LNG – large non-tufted graminoid; LTG – large tufted graminoid; MH – medium herb; MNG – medium non-tufted graminoid; MS – medium shrub; MTG – medium tufted graminoid; PS – prostrate shrub; SC – scrambler/climber; SH – small herb; SS – small shrub; T – tree). Vertical lines (orange) indicate timing of Wiyn Murrup Shaded vertical bars indicate autumn (brown) and spring (green).

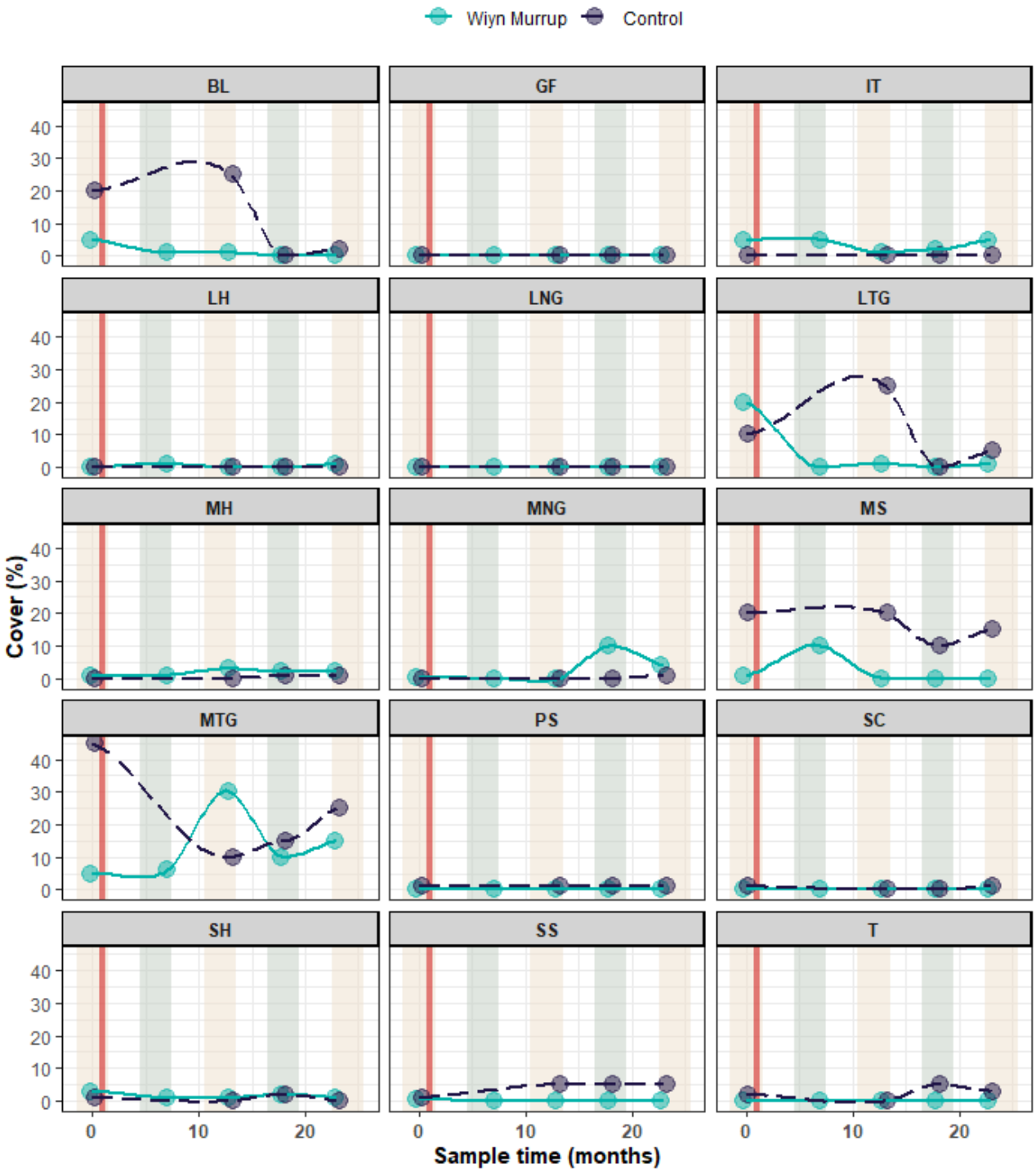

Figure A5.4. Native species cover differentiated into life forms at the Bakers Lane monitoring site.

(BL- bryophytes/lichen; GF – ground fern; IT – immature tree; LH – large herb; LNG – large non-tufted graminoid; LTG – large tufted graminoid; MH – medium herb; MNG – medium non-tufted graminoid; MS – medium shrub; MTG – medium tufted graminoid; PS – prostrate shrub; SC – scrambler/climber; SH – small herb; SS – small shrub; T – tree). Vertical lines (orange) indicate timing of Wiyn Murrup Shaded vertical bars indicate autumn (brown) and spring (green).

Appendix 6 – Model outputs

Table A6. Output from models investigating the influence of time of monitoring in relation to fire (Before vs. After) and Wiyn Murrup (Control vs. Wiyn Murrup) and relevant interactions (Wiyn Murrup x After) year for plant cover, woodland ground cover and structure.

When interpreting the results of a before-after-control-impact (BACI) analysis the interaction term (Wiyn Murrup x After) provides the most useful way of determining if the 'impact' (i.e. Wiyn Murrup) affected the response variables relative to the changes in the 'control' site.

Response variable	Parameter	Estimate	Estimate error	Lower 95% CI	Upper 95% CI
Bare ground cover (%)	Intercept	–2.029	0.2966	–2.6448	–1.4731
	Wiyn Murrup	–0.3142	0.4098	–1.1384	0.4846
	After	–0.0346	0.3078	–0.6578	0.5491
	Wiyn Murrup:After*	**0.873**	**0.4745**	**–0.0516**	**1.8214**
Litter cover (%)	Intercept	–0.1968	0.4103	–1.017	0.5977
	Wiyn Murrup	0.1893	0.4919	–0.7417	1.2138
	After	0.3341	0.2768	–0.2047	0.8748
	Wiyn Murrup:After	–0.4264	0.4286	–1.2776	0.4283
Soil crust cover (%)	Intercept	–2.0899	0.3602	–2.8399	–1.3974
	Wiyn Murrup	–0.0779	0.5304	–1.1143	1.0266
	After	–0.6127	0.3223	–1.2151	0.0735
	Wiyn Murrup:After	0.2237	0.4669	–0.6994	1.1355
Native cover (%)	Intercept	–1.6617	0.322	–2.2702	–1.015
	Wiyn Murrup	–0.0955	0.5286	–1.2659	0.864
	After	–0.4344	0.317	–1.0552	0.1948
	Wiyn Murrup:After	0.4527	0.5634	–0.6806	1.5472
Exotic cover (%)	Intercept	–1.304	0.4234	–2.1478	–0.4404
	Wiyn Murrup	0.4351	0.51	–0.5658	1.4339
	After	0.2374	0.308	–0.3566	0.836
	Wiyn Murrup:After	–0.157	0.4533	–1.0383	0.728
Golf ball score	Intercept	2.0009	–0.4112	1.1955	2.8351
	Wiyn Murrup	–0.8893	–0.5497	–1.9456	0.1973
	After	–0.4959	–0.3155	–1.1169	0.1236
	Wiyn Murrup:After	**2.2431**	**–0.5419**	**1.1259**	**3.2397**

* infers marginal difference (i.e. credible intervals slightly encompassing 0)

Appendix 7 – Woody plant recruitment

Table A7 Recruitment of woody weeds (*) and native small tree/large shrubs (^) for each large quadrat.

Monitoring site	Treatment	Sample time (months)	Large Quadrat	Fire affected quadrats (>10% burnt in last 12 months)	Canopy tree (*Eucalyptus* spp.)	*Galenia (*Aizoon pubescens*)	*Boneseed (*Chrysanthemoides monilifera*)	*Sugar Gum (*Eucalyptus cladocalyx*)	^Wattles (*Acacia* spp.)	^Cheery Ballart (*Exocarpos cupressiformis*)
Bakers Lane	Wiyn Murrup	0	Central	Unburnt	Not assessed					
			East	Unburnt	Absent					
			West	Unburnt	Absent					
		7	Central	Burnt	Low					
			East	Burnt	Low					
			West	Burnt	Low					
		13	Central	Burnt	Low					
			East	Burnt	Low					
			West	Burnt	Low					
		18	Central	Unburnt	Low					
			East	Unburnt	Low					
			West	Unburnt	Low					
		23	Central	Unburnt	Low					
			East	Unburnt	Low					
			West	Unburnt	Absent					
	Control	0	Central	Unburnt	Absent	P			P	
		13	Central	Unburnt	Low	P			P	
		18	Central	Unburnt	Low	P		P	P	
		23	Central	Unburnt	Low				P	
You Yangs	Wiyn Murrup	0	Central	Unburnt	Not assessed		P		P	
			North	Unburnt	Not assessed		P		P	
			South	Unburnt	Not assessed		P		P	
		6	Central	Burnt	Low		P		P	
			North	Burnt	Moderate		P		P	
			South	Burnt	Low		P		P	
		12	Central	Burnt	Low		P		P	
			North	Burnt	Low		P		P	P
			South	Burnt	Low		P		P	
		18	Central	Unburnt	Low		P			

Monitoring site	Treatment	Sample time (months)	Large Quadrat	Fire affected quadrats (>10% burnt in last 12 months)	Canopy tree (*Eucalyptus* spp.)	*Galenia (*Aizoon pubescens*)	*Boneseed (*Chrysanthemoides monilifera*)	*Sugar Gum (*Eucalyptus cladocalyx*)	^Wattles (*Acacia* spp.)	^Cheery Ballart (*Exocarpos cupressiformis*)
			North	Unburnt	Low		P		P	
			South	Unburnt	Low		P		P	
		23	Central	Unburnt	Absent		P		P	
			North	Unburnt	Absent		P		P	P
			South	Unburnt	Absent		P		P	
	Control	0	Central	Unburnt	Absent	P				
			North	Unburnt	Absent	P				
			South	Unburnt	Low					
		6	Central	Unburnt	Absent	P				
			North	Unburnt	Low	P				
			South	Unburnt	Low					
		12	Central	Unburnt	Low	P				
			North	Unburnt	Low	P				
			South	Unburnt	Low				P	
		18	Central	Unburnt	Low	P	P		P	
			North	Unburnt	Low	P				
			South	Unburnt	Low		P			
		23	Central	Unburnt	Absent		P		P	
			North	Unburnt	Low				P	
			South	Unburnt	Absent				P	

Not assessed – no data collected, Absent – 0 individuals observed, Low – 0–10 individuals observed, Moderate – 10–50 individuals observed; P – present.

* Woody weeds

^ Native large shrubs/small trees

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