Ecocultural monitoring reveals low impact of a Dharug dhiyina (women's) guwiyang (fire) in an urban national park, Australia

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Abstract

Indigenous-led fire stewardship is increasingly recognised as important for ecological and cultural resilience; however, remains rare in urban landscapes due to regulatory barriers, fear and risk aversion. This study aligned with the first Dharug *dhiyina* (women's)-led *guwiyang* (fire) since European invasion of *Bidyiwung Badhu Nuru* (Brown's Waterhole) some 230 years ago, in what is now the urban Lane Cove National Park, Sydney. Using a collaborative cross-cultural monitoring approach, we evaluated ecological parameters before and after the *guwiyang* and at three control sites: a modified BACI design. We assessed fuel loads, fire and soil properties, and culturally significant plants and mammals.

The low-intensity, patchy *guwiyan*g had low flame height, slow rate of spread, and significantly reduced surface, near-surface and elevated fuel loads. Following the *guwiyang*, we observed basal resprouting of the culturally significant medicinal plant *Dybung/Mambara* (Geebung, *Persoonia linearis*). As desired by the Dharug women, dominant species, *Daynya* (*Dodonaea triquetra*) and *Gurgi* (*Pteridium esculentum; Calochlaena dubia*) significantly declined post-burn, with short-term regrowth. No significant change was detected in soil properties or activity of *Burraga* (long-nosed bandicoot, *Perameles nasuta*) or *Bagarayi* (swamp wallaby, *Wallabia bicolor*), indicating low *guwiyang* impact, consistent with the intent of the Dharug *guwiyang* for the dense urban woodland context.

This study of a rare Indigenous-led cultural burn in an urban setting demonstrates the mechanics of a cross-cultural partnership that adopted a two-way science approach. We combined Indigenous values and Western science to provide evidence of reduced fuel loads and low ecological impact of the *guwiyang*. Such studies can abate the fear surrounding fire in urban ecosystems, especially those managed by Indigenous custodians. With growing wildfire risks linked to climate change, cross-cultural collaborations offer valuable pathways for ecological and cultural resilience in urban areas.

Positionality Statement

This research was undertaken by a team comprising both Indigenous (Rey) and non-Indigenous Australian researchers (Brennan, Ens, Chang), all affiliated with the university sector who listened and learnt from Dharug Ngurra (Country) as the senior author of this research. The team included expertise from the biological sciences (Brennan, Ens, Chang) and Indigenous research (Rey), informed by each authors longstanding cross-cultural collaborative research partnerships in other contexts. Through this research, we intended to elevate the eco-cultural value of Indigenous fire practices through two-way learning and to enable two-eyed seeing. While we seek to honour and support Indigenous knowledge systems and Dharug Ngurra, we acknowledge that we do not speak on behalf of the values or practices of Dharug custodians and other Dharug Ngurra outside of the study team and location.

1. Introduction

Indigenous urban fire management

Following centuries of the pervasive global to local impacts of European imperialism and colonisation, Indigenous groups worldwide are increasingly reinstating traditional or cultural conservation practices, including fire management (Russell-Smith et al., 2013; Ngurra et al., 2019; Fletcher et al., 2021; Hoffman et al., 2022; Díaz et al., 2023; Rey et al., 2025). However, significant barriers remain, as in contemporary settings, fire management is highly regulated to protect infrastructure and assets, and arguably to prevent large, destructive wildfires (Smith et al., 2021; Williamson, 2022; McCormack et al., 2024). Within urban-bushland interfaces, where native remnant bushland is situated adjacent to densely settled communities, the perceived threat and potential danger of fire is amplified (Bradstock et al., 1998; Darques, 2015; Bento-Gonçalves & Vieira, 2020). This has contributed to substantial risk-aversion in urban fire and vegetation management decision-making. In colonised nations such as Australia, Canada, and the Unites States of America, such caution is further shaped by colonial-era fear of fire and the systematic exclusion and suppression of Indigenous peoples and their land stewardship practices (Lake & Christianson, 2020; Freeman et al., 2021; Smith et al., 2021; Hoffman et al., 2022; McCormack et al., 2024). Indigenous scholars and allies emphasise the ecological and cultural (ecocultural) benefits of decolonising fire management policies in contemporary settings and revitalising nuanced Indigenous fire practices and knowledges that have shaped landscapes for millennia (Bowman & Panton, 1995; Russell-Smith et al., 2013; Neale et al., 2019; McKemey et al., 2022; Pascoe et al., 2023).

Indigenous fire management across many parts of the world reflects broader responsibilities of cultural stewardship, including caring for Country, sustaining resources, and facilitating access to cultural sites (Lake & Christianson, 2020; Fletcher et al., 2021). In sparsely populated and geographically remote areas, Indigenous groups have been able to maintain and revitalise traditional fire practices to a greater extent than in urban landscapes, where land access, legal recognition, and structural barriers have limited such opportunities (Williamson & Weir, 2021; Hoffman et al., 2022; Williamson, 2022). In Australia, this is evident in central and northern regions, where many Indigenous communities have been able to maintain strong access to ancestral lands and opportunities to practice customary traditions, including traditional burning (Russell-Smith et al., 1997; Ansell & Evans, 2019; Williamson, 2022; McCormack et al., 2024). Research within these regions highlights the ecological, cultural, social, and economic benefits of maintaining traditional fire management practices in contemporary settings (see Vigilante & Bowman, 2004; Russell-Smith et al., 2009; Bird et al., 2018; Legge et al., 2024). By contrast, south-eastern Australian Indigenous communities face greater barriers to traditional fire management practice. However, despite constraints, Indigenous fire knowledge persists within urban and regional communities and is being actively revitalised, though often on a smaller scale (Steffensen, 2020; Freeman et al., 2021; Cavanagh, 2022; Pascoe et al., 2023; Rey et al., 2025). Some of this activity has been documented in the academic literature (e.g., McKemey et al., 2019; Neale et al., 2019; Ngurra et al., 2019; Freeman et al., 2021; Cavanagh, 2022; Atkinson & Montiel-Molina, 2023; Weir, 2023; Bowd et al., 2025; Rey et al., 2025), although it is important to acknowledge that many burns conducted by Indigenous Peoples are not documented in mainstream publicly accessible platforms.

Additionally, there is an increasing movement towards reinstating women's-led cultural burning, acknowledging that Indigenous women historically played vital roles in fire management and environmental stewardship, shaped by their gendered cultural responsibilities and ecological knowledge (Bird et al., 2004; Tynan & Cavanagh, 2021; Cavanagh, 2022; Brennan et al., 2024; Rey et al., 2025). Raising awareness of Indigenous women's-led burning is noted as particularly important given the limited research on the roles of Indigenous women in cultural burning, especially in south-eastern Australia, which likely reflects prevailing patriarchal processes (Cavanagh, 2022). Moreover, the disproportionate recognition and involvement of women in broader natural resource management due to colonial and gendered barriers (Sithole et al., 2008; James et al., 2021) is gaining increasing recognition, a gap which the present project and associated research aimed to address.

Benefits of cross-cultural monitoring

Effective monitoring and communication of conservation outcomes, in this case from Indigenous women's-led cultural burning, can enhance understanding and foster broader receptiveness and support (Robinson et al., 2018; Ansell & Evans, 2019), particularly in urban landscapes where cultural practices have been significantly disrupted or suppressed (David et al., 2024). Similar to the process of burning itself, monitoring can also be decolonised to reflect and highlight Indigenous values, knowledge systems, and approaches to caring for Country (Danielsen et al., 2005; McKemey et al., 2019; Skroblin et al., 2022). Moreover, research indicates that increased collaboration between Indigenous Peoples and Western-trained scientists can deliver enhanced cross-cultural learning and conservation outcomes (Ens et al., 2015; Eloy et al., 2019; Bourke et al., 2020; Fletcher et al., 2021).

Cross-cultural, two-way, right-way or two-eyed seeing approaches that combine Indigenous and Western knowledge systems and methods offer space for more genuine and respectful collaborations and inclusion (Bartlett et al., 2012; Ens et al., 2015; Ens & Turpin, 2022; McKemey et al., 2022). Although cultural burning remains rare in urban settings, Australian (McKemey et al., 2022; Bowd et al., 2025; Ngurra et al., 2025) and international examples (Christianson, 2014; Nikolakis & Ross, 2022) demonstrate how cross-cultural partnerships and effective monitoring can promote ecological, cultural, and social outcomes and abate the fear associated with fire in nearby habitats. For example, in central regional Victoria, Australia, the Dja Dja Wurrung have collaborated with bushfire management agencies to reactivate cultural burning through cross-cultural partnerships through "decolonising experiments" in fire management (Neale et al., 2019). Similarly, on the New South Wales tablelands, cross-cultural monitoring by Banbai people and scientists demonstrated that low-intensity cultural burning had less impact on the foraging activity of the culturally significant short-beaked echidna (*Tachyglossus aculeatus*) and the mortality of Backwater grevillea (*Grevillea scortechinii subsp. sarmentosa*) than nearby prescribed burns (McKemey et al., 2019; McKemey et al., 2021). On the southeast coast of Australia, cultural burning has also been shown to have positive effects on soil health, such as facilitating the input of organic matter and increasing soil moisture, which in turn impacted overall ecosystem responses (Country et al., 2024). Internationally, Indigenous groups like the Yunesit'in in North America, have applied collaborative approaches by drawing on deep ecological knowledge and "learning by doing" to restore fire practices following colonial disruptions (Nikolakis & Ross, 2022). On Secwépemc territory in North America (British Columbia), collaborative research found that low-severity burns undertaken by Secwépemc people were linked to greater richness of culturally significant plant species, highlighting the role of traditional fire practices in sustaining valued resources (Dickson-Hoyle et al., 2024). All these examples demonstrate the benefits of cross-cultural approaches to monitoring Indigenous-led fire; however, we could find no examples for urban ecosystems.

Exploring cultural guwiyang (fire) in urban landscapes

Despite the growth of Indigenous cultural burning in remote and regional contexts, there remains a dearth of burning and associated research in urban landscapes, including southeastern Australia (Neale et al., 2019; Pascoe et al., 2023; Rawluk et al., 2023). Novel approaches to urban biodiversity management are crucial, as these areas face disproportionately high species loss due to habitat fragmentation, invasive species, altered fire regimes, and urban encroachment (Fitzgibbon et al., 2011; Kirkpatrick et al., 2023).

In the fragmented environments of Sydney, Australia, conservation of small, ground-dwelling animals such as the long-nosed bandicoot (*Perameles nasuta*), in part, requires the maintenance of habitat mosaics that include dense refuges and open foraging areas; conditions that were likely historically sustained by fire (Scott et al., 1999). Despite urban encroachment, remnant habitat patches serve as critical refuges for native species. For instance, southern brown bandicoots (*Isoodon obesulus obesulus*) have persisted in human-modified landscapes and may benefit from repeated low-intensity burns, although foraging may initially decline after fire (Maclagan et al., 2018; Kirkpatrick et al., 2023). Such studies highlight a complex interplay between fire frequency, habitat condition and urban pressures, reinforcing the need to consider cultural burning as a nuanced fire management strategy in fragmented urban-bushland interfaces.

Cultural guwiyang around the global city of Sydney

In the Sydney Basin, early European colonial records and palaeoecological studies indicate that prior to European colonisation, Indigenous Dharug people and neighbouring groups used fire to manage their ancestral clan estates (Clark & McLoughlin, 1986; Kohen, 1986; McLoughlin, 1998; Black & Mooney, 2007; Gammage, 2013; Jurskis & Underwood, 2013). Following European colonisation, cultural fire practices were widely suppressed across south eastern Australia (Cahir et al., 2018; McCormack et al., 2024), including within the Sydney Basin, where burning largely ceased (Attenbrow, 2010). This was likely a result of the dispossession of local Indigenous groups from their lands and the disruption of cultural practices (Brook & Kohen, 1991; Karskens, 2009). Despite these significant impacts on traditional custodial responsibilities, Dharug are reigniting and continuing cultural practices across *Ngurra* (Country), including restoring *guwiyang* (fire) as a deliberate act of restorative healing for *Ngurra* and the community (Ngurra et al., 2019; Rey et al., 2025).

The present study focused on the recent revitalisation of Indigenous cultural burning in Sydney, where such actions and research remain sparse, especially concerning the contributions of Indigenous women (Cavanagh, 2022; Rey et al. 2025). Through a cross-cultural collaboration between Dharug women and university scientists at *Bidyiwung Badhu Nuru* (Brown's Waterhole), Walumadagal *Ngurra*, this study explored the ecocultural responses of 'other-than-human' (biophysical) landscape elements to a low-intensity Dharug *dhiyina* (women's)-led cultural burn (see Appendix 1 for a glossary of Dharug terms). The Dharug *dhiyina* identified the following key objectives for the burn: (1) Create a low intensity fire to minimise ecological impacts while reducing fuel loads for wildfire mitigation; (2) Protect culturally significant plant species, such as *Dybung/Mambara* (narrow-leaved geebung, *Persoonia linearis*), and reduce the dominance of *Daynya* (common hop bush, *Dodonaea triquetra*) and *Gurgi* (bracken ferns, *Pteridium esculentum; Calochlaena dubia*); (3) Understand the fire's influence on soil properties; and (4) Ensure minimal impacts on fauna, with a focus on the culturally important mammal species: *Burraga* (long-nosed bandicoot, *Perameles nasuta*) and *Bagarayi* (swamp wallaby, *Wallabia bicolor*).

2. Methods

2.1. Co-developing cross-cultural approaches

In 2023, the Dharug Women's and Allies Cultural Fire Alliance (DWACFA) invited non-Indigenous researchers (Authors GB, EE, MC) to assist with cross-cultural monitoring of 'other-than-human' outcomes of a cultural *guwiyang* led by Dharug *dhiyina*. This research complements prior socio-cultural research led by Dharug researcher and author JR (Rey, 2022), as well as previous and ongoing Dharug-led cultural burns in western Sydney (Ngurra et al., 2019; Ngurra et al., 2025). The co-development of the cross-cultural monitoring program occurred through a series of yarning sessions (see Bessarab & Ng'Andu, 2010) between JR, EE, MC and GB. These discussions focused on key interests and questions raised by the DWACFA regarding the proposed cultural burn, building on exploratory biocultural monitoring previously conducted by the DWACFA, which included recording edible, medicinal, and useful plants and animals using electronic data collection software CyberTracker (Liebenberg, 2012), alongside camera traps. Through these yarning sessions, we identified specific Dharug interests and aspirations for 'other-than-human' responses to the proposed *guwiyang*, such as soil, fauna and useful Dharug plants.

2.2. Study sites

The Dharug-led cultural *guwiyang* was undertaken in April 2024 at *Bidyiwung Badhu Nuru*, Lane Cove National Park (LCNP), in north-west Sydney, Australia (Fig. 1). This site holds cultural significance and ancestral connection for the co-author JR (Rey, 2021). It is also an important urban habitat refuge for threatened plant and fauna species (Reidy et al., 2005), within an urban residential and light commercial zone adjacent to Macquarie University (Office of Environment and Heritage, 2016). The planned cultural *guwiyang* area was relatively small, as Dharug *dhiyina* wanted to tread slowly to avoid instilling fear, and target the dominant *Daynya* and *Gurgi*. Hence, the study area reflected this aim and covered a 30mx30m area. To assess 'other-than-human' responses to the *Bidyiwung Badhu Nuru* (impact site) *guwiyang*, we compared characteristics to three adjacent control sites. Control sites were selected within 2km of the burn site in LCNP and between 300-900m apart (access dependent), with similar habitat/vegetation type, aspect, slope, and proximity to the Lane Cove River (~ 20m) (Fig. 1). This approach followed the modified BACI (Before-After, Control-Impact) monitoring design of Underwood (1994) for a single impact site and multiple control sites (Pardini et al., 2018).

The study was located within the Sydney Enriched Sandstone Moist Forest (sclerophyll) vegetation type (Fig. 1; DCCEEW, 2020). The soil is primarily classified as rudosol, characterised by well-drained sand and gravel composition (Department of Planning, 2021). Dominant tree species included: Sydney peppermint (*Eucalyptus piperita*), red bloodwood (*Corymbia gummifera*), Sydney red gum (*Angophora costata*) and blackbutt (*Eucalyptus pilularis*). Mid-storey species included: *Dybung/Mambara* (broad-leaved geebung, *Persoonia levis;* narrow-leaved geebung, *Persoonia linearis*), linear-leaf grevillea (*Grevilliea linerifolia*), blueberry ash (*Elaeocarpus reticulatus*) and *Gulgadya* (broadleaf grass-tree, *Xanthorrhoea arborea;* grass tree, *Xanthorrhoea media*). Dominant ground cover species were: *Gurgi*, *Bamuru* (spiny-headed mat-rush, *Lomandra longifolia*), pithy sword-sedge (*Lepidosperma laterale*), *Warabura* (sweet sarsaparilla, *Smilax glyciphylla*) and snake vine (*Stephania japonica*). At the burn site, *Daynya* was dominant in the mid-ground story in some areas. *Daynya* is known to occupy disturbed sites (Country et al., 2024).

Bidyiwung Badhu Nuru (Brown's Waterholewas partially burnt 5 years prior to the cultural *guwiyang* during an arson-related bushfire in 2019. This followed a prescribed burn conducted across the entire site in 2018. Before these events, the site had not experienced fire for 16 years (Table 1). Two control sites, Middle Site and Devlin's Creek, were last burned by prescribed fires in 2018 and 2010, respectively. Additionally, all sites had been impacted by bushfire in 2001/2002. According to JR, the proposed cultural burn at *Bidyiwung Badhu Nuru* was "an historic cultural burn… It's the first time since the early colonial period that Dharug have burnt there".

Table 1
Fire histories and time since last fire of each monitoring site, including bushfires (BF) and prescribed burns (PB) (DCCEEW, 2010).

Site Name	Fire Histories	Time Since Last Fire (from 2024)
Terry's Creek	2002 (BF)	22 years
Bidyiwung Badhu Nuru	2019 (BF), 2018 (PB), 2002 (BF)	5 years
Middle Site	2018 (PB), 2002 (BF), 1993/1994 (BF)	6 years
Devlin's Creek	2010 (PB), 2002 (BF), 1993/1994 (BF), 1976 (BF)	13 years

2.3. Cultural burn process

Throughout the cultural journey, several stakeholder days were held before the burn, engaging the Dharug community and local river 'neighbours' (see Rey et al., 2025), as shown in Fig. 2. These events served as important communication channels and opportunities for relationship-building between the

Dharug and non-Indigenous residents and stakeholders, thereby supporting the cultural *guwiyang* process. Prior to the cultural burn, DWACFA ran a four-day workshop in March 2024 (Fig. 2), which involved cultural preparations for the site. One week before the cultural burn, the Dharug *dhiyina* trimmed the *Daynya* stems (from ~ 2m to ~ 50 cm) to reduce the fuel load and likelihood of intense burning, as they wanted to impart a 'cool' traditional cultural burn. The cultural burn was undertaken across four days in late April 2024, led by the DWACFA, with other Dharug, Indigenous and non-Indigenous community members, stakeholders, and New South Wales government National Parks and Wildlife Service staff. As outlined in Rey et al. (2025), Dharug *dhiyina* led the burn, beginning at the highest point of the site (west) and moving across in groups, using multiple ignition points to create fire mosaic patches or circles. Rake hoes were used to create containment lines and control the fire. Rain in the weeks leading up to the burn (Fig. 3), meant that the fuel was moist and the vegetation and leaf litter was difficult to ignite and hence, spread slowly. As the temperature increased as the sun passed over the site, the fire spread more easily. Some plants species, such as *Gurgi*, were especially slow to catch fire, requiring encouragement to alight through dried *Gulgadya* leaves (Rey et al., 2025). Some of the previously cut *Daynya* stems did not fully burn. Average wind speed was 17.25 km/h in the morning and 16.25 km/h in the afternoon, with a mean maximum temperature of 23°C and minimum of 12.4°C over the four days (Bureau of Meteorology, 2025). There was also substantial rain in the week following the burn (~ 13.26 mm) (Fig. 3).

2.4. Biocultural monitoring

At each impact and control site, we established six 15x10m^2 grids with three nested 1m^2 quadrats in each grid cell using randomly generated coordinates (Fig. 4). The following assessments were undertaken within this schema.

2.4.1. Cultural guwiyang assessment

To assess fuel hazard changes at the impact site before and after the *guwiyang*, leaf litter depth (mm) was measured using a ruler within each quadrat. Additionally, percentage vegetation cover below 2 m was visually estimated as a measure of near-surface (≤ 0.6 m) and elevated (0.6–2 m) fuel strata, as defined by Hines et al. (2010). These low-mid storey cover data were combined into a single metric for rapid assessment. At nine to ten ignition points on each of the three burn days, we measured: (1) the rate of spread (how many metres the fire moved in one-minute); and (2) the visually estimated flame height at each ignition point (McStephen, 2014; AFAC, 2015). Following the burn, we measured scorch height and proportion of area burned (patchiness) in each 1 m^2 quadrat (n = 18) (Ooi et al., 2006; McStephen, 2014; McKemey et al., 2019).

2.4.2. Dharug plant surveys

Dharug plant surveys were conducted before (early April 2024) and after the *guwiyang* (mid-July 2024) (Fig. 2). Dharug collaborators identified the following three plant species of interest for the fire response monitoring: *Daynya*, *Gurgi* and *Dybung/Mambara* (narrow-leaved geebung, *Persoonia linearis*). Within the

$1m^2$ quadrats, we counted living *Daynya* stems and estimated *Gurgi* frond percentage cover. Within each grid cell, we assessed culturally valued and fire responsive Dharug bushfood/medicine *Dybung/Mambara* (Morrison & Renwick, 2000) by counting the number of resprouting shoots at the base of adult plants (Morrison & Renwick, 2000; Benwell, 2024), with cluster of shoots counted as one.

2.4.3. Soil properties

Soil samples were taken at randomly generated locations within each grid cell at each site, one week before and one week following the *guwiyang* (Fig. 2). Soil samples were collected using a 10cm steel core ring and placed in sealed plastic bags and stored at 4°C prior to analysis.

From each sample, a 50 g sub-sample was weighed and oven-dried at 105°C for four days, then re-weighed to determine soil water content (differential weighing method; (O'Kelly, 2004). After weighing 10 g sub-samples, rocks and organic material (e.g., leaf debris, twigs) were removed, and the remaining soil was finely ground. From this, we measured carbon content (loss on ignition), pH and electrical conductivity. For loss on ignition, 3g of soil was placed in a crucible, heated at 550°C for four hours, and re-weighed (Hoogsteen et al., 2015). pH and electrical conductivity were measured from a 1:5 soil-to-water solution (5 g soil:25 g water) using a Multi-parameter PCSTestr 35 probe.

2.4.5. Fauna survey

Camera traps were used to detect ground-dwelling Dharug target animals across four survey periods: six months before (September/October 2023), six weeks before (March/April 2024), immediately after (May/June 2024) and three months after (July/August 2024) the *guwiyang* (Fig. 2). Six Reconyx HP2W cameras were deployed at each site with one placed in each grid cell, approximately 15m apart, for 35 trap days per period. Cameras were fixed to trees, and vegetation was cleared directly in front of the camera to avoid false triggers. Cameras were set to white flash, capturing three pictures per second with high sensitivity. Cameras were placed 40cm above ground and facing down at a 45 degree angle (Meek et al., 2012; Gigliotti et al., 2022). A peanut butter, honey and oat lure was used in a PVC pipe bait station (Paull et al., 2011), mounted on a star picket with cable ties, and placed 1.2m from the camera. An active 'lure' survey approach was adopted, to increase likelihood of animal detection and strengthen data analysis (following Miritis et al., 2024; Watchorn et al., 2024). Fauna monitoring methods were approved by Macquarie University Animal Ethics Committee (Reference number: 520251964364056) and consent for monitoring was approved by NSW National Parks and Wildlife Services (Reference number: DOC22/1022834).

2.5. Data analysis

During the Dharug *guwiyang*, one grid cell did not burn, so only five cells from each monitoring grid were used for each site to balance the data. Statistical tests were dependent on data characteristics, including distribution, sample size, and study design (see Supplementary Table S1 for a summary of statistical analysis type). All analyses were undertaken using R Studio (Version 12.1; R Core Team, 2024).

2.5.1. Fire intensity and fuel hazard analysis

At the impact site, paired Wilcoxon signed-rank tests were used to assess differences in leaf litter depth and vegetation cover below 2m, and means were interpreted against fuel hazard strata thresholds defined by Hines et al. (2010). Fire intensity measures were averaged across samples and reported as means with standard error and sample size. Observed fire intensity was determined using standard fire monitoring codes developed by McStephen (2014).

2.5.2. Plant analysis

Dybung/Mambara reshooting stems were log-transformed and analysed using linear mixed effects models (grid number as random effect), to assess any differences between the impact site and two of the three control sites where they were present. Residual diagnostics were conducted to evaluate assumptions of normality and homoscedasticity, alongside a Shapiro–Wilk test for normality of residuals.

To compare living *Daynya* stem counts and *Gurgi* frond cover before and after the fire, we used the Wilcoxon signed-rank test, given the non-normal distribution of the data and the repeated-measures design. These were only analysed at the impact site, *Bidyiwung Badhu Nuru*, as they were limited at the control sites, and the Dharug *dhiyina* wished to understand whether this species would decline in abundance after the cultural burn.

2.5.3. Soil analysis

Each soil property (pH, EC, soil moisture and carbon content) was analysed individually using linear mixed effects models (grid number as random effect) to assess any potential impact of the *guwiyang* compared to all control sites. Residual diagnostics were conducted to evaluate assumptions of normality and homoscedasticity for each model. Additionally, Shapiro–Wilk tests were used to test for normality of residuals.

2.5.4. Fauna analysis

For each animal detection, camera trap images were tagged with date, event duration (start and end time) and species (*Bagarayi* (Swamp wallaby; *Wallabia bicolor*) and *Burraga* (Long-nosed bandicoot; *Perameles nasuta*)). Given the close proximity of cameras within each site and the small scale of the burn, we pooled detections from all cameras within a site to avoid pseudo-replication and overinflating detection estimates. For each site, daily species detections were aggregated and recorded as present (1) or absent (0) per day within each survey period (Miritis et al., 2024). Presence/absence data were aggregated across survey periods, with the response variable defined as species activity (Parkins et al., 2019; Miritis et al., 2024; Watchorn et al., 2024) that was calculated as the number of days present divided by the total number of days within each survey period.

To assess whether *Burraga* and *Bagarayi* activity responded to the *guwiyang*, we employed generalised linear models (GLMs) with binomial errors and a logit link function for each species (Bolker et al., 2009;

Pardini et al., 2018). The model tested whether the interaction between survey period and treatment type (the BACI effect) explained significant variation in species activity (as in Pardini et al., 2018). The two pre-burn surveys were grouped as 'before' and the two post-burn surveys as 'after'. In the model, *Bidyiwung Badhu Nuru* was specified as the impact site and used as the reference level, while the three control sites were included individually to enable direct comparisons. All models were fit using the *glm* function from base R. The significance of fixed effects was assessed using Type III Wald's χ^2 tests (likelihood ratio tests) using the *car* package (Bolker et al., 2009; Fox & Weisberg, 2018). Model fit was evaluated using McFadden's R^2, calculated with the *pscl* and *performance* packages. Assumptions were assessed using *DHARMa* package to examine residual distributions and check for overdispersion. Post hoc pairwise comparisons of estimated marginal means were conducted using the *emmeans* package to test before-after changes within each site.

3. Results

3.1. Cultural *guwiyang* intensity and fuel hazard assessment

Following *Bidyiwung Badhu Nuru guwiyang*, there was a significant reduction in surface fine fuel loads (V = 114, p = 0.002); mean leaf litter depth declined from 30.3 mm (± 10.6mm SE, n = 15) to 8.3 mm (± 9.4mm SE, n = 15). According to Hines et al. (2010), this shift reflected a reduction in surface fuel hazard from high (≥ 20 mm) to low (< 10 mm). Similarly, mean vegetation cover below 2 m decreased from 58.0% (± 19.8% SE) to 19.0% (± 12.4% SE), a significant reduction in vertical fine fuel strata (V = 119, p = 0.0009). Based on cover thresholds, this corresponded to a decline in fuel hazard from high (> 50%) to low–moderate (10–40%) across the near-surface and elevated fuel strata (Hines et al., 2010). During the burn, the estimated mean flame height was 0.96m (± 0.1 SE, n = 28) and the rate of spread was 0.48m/minute (± 0.04m SE, n = 28). On average, 52.67% (± 7.74% SE, n = 15) of each quadrat was burnt and the mean scorch height was 1.1m (± 0.19m SE, n = 15). According to protocols outlined by McStephen (2014), the observed fire intensity was low, as it was patchy, did not remove all the litter and ground stratum, and there was very low scorch with no canopy scorch.

3.2. Dharug plant responses

There were significantly more *Dybung/Mambara* shoots after the *guwiyang* (β = -0.88, SE = 0.20, p < 0.001). The interaction effect indicated that the before-after changes at Devlin's Creek (β = 0.72, SE = 0.29, p = 0.021) and Terry's Creek (β = 0.88, SE = 0.29, p = 0.006) were significantly different from the impact site. Post hoc results showed no significant change at Devlin's Creek or Terry's Creek (p > 0.4), indicating that the observed increase was confined to the *Bidyiwung Badhu Nuru guwiyang* site.

After the *guwiyang*, significant reductions in living *Daynya* stems (V = 28, p = 0.022) and *Gurgi* frond cover (V = 75, p = 0.005) were detected. However, new *Gurgi* fronds were observed within weeks after the fire.

3.3. Dharug soil responses

Soil moisture increased at all sites following the *guwiyang*, including at *Bidyiwung Badhu Nuru* where the increase was statistically significant ($\beta = -10.5$, SE = 3.11, $p = 0.002$; Fig. 5). However, no significant interaction was found between site and survey period, indicating that similar increases were also observed at control sites (Devlin's Creek: $\beta = 4.99$, $p = 0.27$; Middle Site: $\beta = 5.47$, $p = 0.22$; Terry's Creek: $\beta = 4.30$, $p = 0.34$).

No significant changes were detected in soil carbon, pH, or electrical conductivity after the *guwiyang* at *Bidyiwung Badhu Nuru*, and no significant interaction effects were found between site and survey period, indicating that any variation observed at the impact site was comparable to that at control sites (Fig. 5; see Supplementary Table S2 for full model outputs).

3.3. Dharug fauna responses

We found no substantial effect of the *guwiyang* on either target fauna species over the study period compared to the control sites. *Burraga* activity before and after the *Bidyiwung Badhu Nuru guwiyang* did not significantly differ from other sites ($\chi^2 = 2.54$, df = 3, $p = 0.468$). Model-estimated activity probabilities showed a significant decline in *Burraga* activity across all sites (Fig. 6; see Supplementary Table S3 for full model outputs). At *Bidyiwung Badhu Nuru*, activity dropped sharply ($p = 0.0002$), representing an ~ 8.6-fold reduction. Similar but less pronounced declines were observed at the control sites: Devlin's Creek declined ~ 2.7-fold ($p = 0.045$); Middle Site ~ 4.1-fold ($p = 0.017$); and Terry's Creek ~ 4.5-fold ($p = 0.011$). DHARMa residual diagnostics indicated no evidence of overdispersion or poor model fit. The model explained 34.6% of the variance in *Burraga* activity (McFadden's R^2), indicating a moderately strong fit.

Changes in *Bagarayi* activity before and after the *guwiyang* differed between sites ($\chi^2 = 16.70$, df = 3, $p < 0.001$) (Fig. 6). At Middle Site, activity was reduced by nearly half ($p < 0.001$). In contrast, there were no significant differences before-after fire at *Bidyiwung Badhu Nuru* (~ 1.3-fold, p = 0.177), Devlin's Creek (~ 1.2-fold decline, p = 0.309) or Terry's Creek (~ 1.1-fold decline, p = 0.396). Residual diagnostics confirmed appropriate model fit and no overdispersion. The model explained 20.6% of the variance in *Bagarayi* activity (McFadden's R^2).

4. Discussion

Cultural guwiyang in urban landscapes

Despite growing international interest in and application of Indigenous cultural burning for ecological and cultural purposes, there is a paucity of burning and associated research in urban landscapes. The present paper addresses this research gap through cross-cultural monitoring of a Dharug *dhiyina* (women's)-led cultural *guwiyang* (fire) event in the urban-bushland interface of Lane Cove National Park, Sydney, Australia. Ecocultural responses of the 'other-than-humans' were varied and nuanced, but overall provided evidence for the low ecological impact of the cultural *guwiyang* at *Bidyiwung Badhu Nuru* (Brown's Waterhole), aligning with the Dharug *dhiyina* objectives for the burn (Rey et al., 2025) and other existing yet limited studies in south-eastern Australia (McKemey et al., 2019; McKemey et al., 2021). Evidence of the low intensity and impacts of Indigenous-led cultural burns in urban areas is useful for guiding decisions about including Indigenous peoples and knowledge in urban ecosystem management and helps to reduce barriers related to fear and lack of data that influence fire management policies (Williamson, 2022; McCormack et al., 2024). Notably, this *guwiyang* was planned and implemented by Dharug *dhiyina*, addressing a critical gap in practice and research regarding the impacts of cultural burning informed by Indigenous women's values and gendered knowledge systems, which have historically been underrepresented (Sithole et al., 2008; James et al., 2021; Cavanagh, 2022; Rey et al., 2025).

Fuel and fire behaviour of the cultural guwiyang

Post-burn reductions in surface fine fuels and near-surface/elevated fuels (Hines et al., 2010) suggest that this cultural *guwiyang* lowered fuel hazards at *Bidyiwung Badhu Nuru*, aligning with one of the Dharug *dhiyina* objectives. Burning intensity measures confirmed the patchy, low-intensity approach that was preferred by the Dharug women, aligning with other cultural burns studied in eastern Australia (McKemey et al., 2019). Furthermore, the Dharug *dhiyina guwiyang* fell within or below the recommended prescribed burning thresholds for rate of spread and flame height for sclerophyll forests (McCarthy, 2004; AFAC, 2015; Cruz et al., 2015).

These findings are noteworthy given the colonial legacy of distrust and suppression of Indigenous fire practices (Cahir et al., 2018; Hoffman et al., 2021). While public attitudes are shifting, fear and concerns surrounding strategic fire use (such as escape risks, smoke and ecological consequences) often limit public support for burning in populated urban-bushland areas (Cortner et al., 1990; Bell & Oliveras, 2006; Altangerel & Kull, 2013). The results of the present study add to the growing evidence that cultural burning, like other low-intensity, patchy burns, can reduce fuel loads (McCarthy, 2004), potentially contributing to a reduction in wildfire risks (Boer et al., 2009; Penman et al., 2011) and protection of habitats for fire-sensitive species (Pastro et al., 2011). Paradoxically, there is also evidence for community concern that burning can be too frequent or intense in some cases, potentially affecting regeneration and fauna habitats (Altangerel & Kull, 2013). In this complex fire management context of the urban-bushland interface, cultural burning may offer a complementary approach to mainstream fire management, with not only ecological benefits and reduced wildfire risk, but also socio-cultural benefits that align with international and national goals for enhancing Indigenous inclusion in conservation and science (Price et al., 2012; McKemey et al., 2019; Country et al., 2024; McCormack et al., 2024).

'Other-than-human' responses to the Bidyiwung Badhu Nuru guwiyang

Plants

This study provided data that affirmed the Dharug *dhiyina* objectives for the *guwiyang* including promotion of culturally valued plant species, particularly the medicine and food plant, *Dybung/Mambara*, which responded by producing regenerative shoots. This species of Geebung is known to tolerate both low- and high-intensity fires by resprouting from basal trunks, lignotubers, or root systems. Notably, low-intensity burns typically yield a higher number of shoots, which may enhance the long-term persistence of the species (Morrison & Renwick, 2000) and produce fresh shoots of medicinal value. However, it is important to consider that other factors, including reduced competition, increased light and nutrient availability, and altered climatic conditions, may have also contributed to the reshooting response (Benwell, 2024).

The cultural *guwiyang* also aligned with the Dharug *dhiyina* objective to reduce the abundance of *Daynya* (hop bush) stems and *Gurgi* (bracken) frond cover (in the short term), as evident by the minimal regrowth three months after the fire. While moderate-intensity fire has been shown to stimulate germination of *Daynya*, the lack of post-fire recruitment detected in the three months after the event, suggested that the low intensity of the cultural *guwiyang* may not have reached the heat threshold required to break seed dormancy (Floyd, 1966). Ongoing monitoring will be essential to assess whether *Daynya* re-establishes and to determine the potential of cultural burning as a longer-term management tool, particularly given that it has been observed to recolonise densely, albeit typically following higher-intensity prescribed fires (Country et al., 2024).

Gurgi also declined in the short-term following the *guwiyang*. Although low-intensity fire is known to temporarily reduce the dominance of this species, recovery is strongly influenced by factors such as sunlight, canopy cover, and rainfall (Spencer & Baxter, 2006; Fernanda & Pavel, 2022). In many cases, *gurgi* has been noted to return to pre-burn levels within six months, particularly in frequently burnt areas, given its ability to regenerate rapidly after fire through sprouting from dormant rhizomes (Tolhurst & Turvey, 1992; Spencer & Baxter, 2006). As such, the long-term effectiveness of cultural *guwiyang* in managing *gurgi* remains uncertain, and continued monitoring will be essential to determine whether repeated cultural burns can reduce dominance of this species over time.

Soils

The Dharug women also expressed interest in understanding changes in soil properties following the *guwiyang*, given the importance of soil in post-fire ecological recovery (Calderisi et al., 2025). No significant change in soil carbon was detected, consistent with other low-intensity fire studies (e.g., Granged et al., 2011; Plaza-Álvarez et al., 2017). In contrast, substantial increases in carbon have been observed following other Indigenous-led or moderate-intensity prescribed burns (Granged et al., 2011; Country et al., 2024). This has been attributed to black carbon produced from partially combusted material at lower temperatures (Xifré-Salvadó et al., 2021), which is often visible as black ash—an indicator of cool-burning, also noted by the Dharug *dhiyina* in conversation. In addition, no significant changes in soil moisture, pH, or electrical conductivity were measured after to the burn. While responses in soil moisture and pH vary across low-intensity fire studies (Granged et al., 2011; Country et al., 2024), the stability of electrical conductivity observed here aligned with findings by Granged et al. (2011). Overall, these outcomes likely reflect the low intensity and patchy coverage, along with post-fire rainfall and limited ash production from incomplete combustion, which together contributed to the minimal impact of the cultural *guwiyang* on soil properties (Granged et al., 2011; Xifré-Salvadó et al., 2021; Country et al., 2024).

Fauna

The cultural *guwiyang* also appeared to have limited effects on *Bagarayi* (swamp wallaby) and *Burraga* (long-nosed bandicoot) activity, reflecting the small scale and low impact of the burn. Previous research has shown that swamp wallabies can respond positively to recent burns, which stimulate the regrowth of preferred food sources such as fungi and grass shoots (Stefano et al., 2009; Chard et al., 2021). In this study, camera trap photos captured *Bagarayi* feeding on newly emerged fungi and grasses within a month post-burn, coinciding with a slight, though non-significant, increase in activity, mirroring short-term trends observed by Chard et al. (2021). Despite known preferences for areas with dense understorey (Fischer et al., 2019), our results suggest that changes to low- and mid-storey vegetation following the burn did not deter *Bagarayi* at *Bidyiwung Badhu Nuru*. This may be due to the patchy nature and small scale of the burn, which maintained surrounding refugial habitat and likely mitigated the increased predation risk from exposed understorey (Chard et al., 2021).

In contrast, *Burraga* activity decreased across all sites, with the most pronounced drop observed at the burn site. While this reduction might indicate some sensitivity to fire, similar declines at the control sites suggest broader ecological or seasonal influences. *Burraga* are considered well-adapted to small, low-intensity burns in peri-urban areas, particularly when unburnt patches and fire refugia are available (Hope, 2012). In their study of locally vulnerable *Burraga* populations at North Head, Sydney, Scott et al. (1999) emphasised that maintaining a mosaic of open foraging areas alongside dense refuges, likely historically sustained by fire regimes, is a crucial management strategy for this species. They propose that this approach is particularly important in fragmented urban landscapes, where *Burraga* populations face increased risks from introduced predators and motor vehicles. Nonetheless, structural habitat changes following the burn may have contributed to the decline in activity at *Bidyiwung Badhu Nuru*, as *Burraga* are known to prefer dense, unburnt vegetation and typically recolonise burnt areas gradually as cover regenerates (Arthur et al., 2012; MacGregor et al., 2013; Mikac et al., 2023). However, short-term seasonal fluctuations and conditions were likely the over-riding factor that influenced *Burraga* activity patterns in this study, given that these decreases were not unique to the impact site. *Burraga* foraging is known to increase with warmer temperatures and moist soils that support invertebrates and hypogeous fungi, which are key food resources that decline under dry conditions (Claridge & Barry, 2000; Hughes & Banks, 2011). Reproductive activity in nearby urban-bushland populations was shown to peak in late spring and summer, declining during the colder months, likely due to energetic constraints and reduced food availability (Scott et al., 1999). This seasonal variation can, in turn, influence detection probabilities throughout the breeding season (MacGregor et al., 2020). Taken together, cooler post-burn temperatures and fluctuating rainfall may have influenced both foraging and detectability of *Burraga* across all sites.

Long-term monitoring under similar seasonal conditions would be beneficial for disentangling fire-related effects from broader ecological trends.

The mammal responses studied here are particularly relevant within urban-bushland interfaces, where remnant vegetation is fragmented, frequently disturbed, and bounded by residential development. In such landscapes, fauna must navigate a range of non-fire stressors, including habitat degradation, edge effects, and human activity that may compound or obscure responses to fire. The limited impacts observed here suggest that patchy, low-intensity cultural *guwiyang* may be ecologically suitable in urban-bushland settings, supporting species by maintaining habitat mosaics (Scott et al., 1999). Such practices may offer a culturally grounded alternative to conventional prescribed burns that are often larger and hotter, contributing to a more nuanced approach to fire management in fragmented urban landscapes.

Implications for management

This study examined the impacts of a relatively small cultural burn in an urban National Park, providing rare insights into the responses of the ecocultural 'other-than-human' entities. Due to bureaucratic processes, fears surrounding fire, and a lack of broader public understanding and trust of Indigenous fire in urban landscapes, the primary outcome of this research was to demonstrate that low-intensity cultural burns can be conducted with minimal impact. Using standard Western ecological measures, we showed that the Dharug *dhiyina*-led *guwiyang* was low-intensity and patchy, effectively reducing surface and near-surface/elevated fuel loads, while having minimal biophysical impacts on plants, soils, and fauna. Additionally, we quantified the positive effects of the cultural *guwiyang* in decreasing the prevalence of dominant plant species whilst promoting a culturally valued, medicinal and food species. The results contribute to growing evidence that Indigenous-led fire events, when applied appropriately, can support healthy ecosystems, cultural revitalisation and mitigate wildfire risk (Cortner et al., 1990; Hoffman et al., 2021).

Furthermore, these outcomes underscore the importance of cross-cultural, two-way monitoring approaches which, in this context, combined Dharug knowledge with Western scientific methods, fostering opportunities for respectful collaboration, shared learning, and joint decision-making in fire management (Ens et al., 2015; McKemey et al., 2022). Other cultural outcomes of this *Bidyiwung Badhu Nuru guwiyang*, as noted in a complementary publication (Rey et al. 2025), included increased confidence of the Dharug *dhiyina* to conduct burning in the urban-bushland interface. The burn also helped alleviate fears among neighbours and stakeholders, and community cohesion around the common goal of caring for *Ngurra* (Country) while reducing wildfire risk to local infrastructure. While the results of this burn and associated monitoring are promising, we recognise that they provide only a limited snapshot of the cultural and biophysical responses of the cultural burn. To gain a deeper understanding of changes and recovery, particularly concerning fauna, longer-term post-fire monitoring across a greater number of larger impact and control sites would be highly beneficial. Cross-cultural monitoring of the Dharug-led *guwiyang* captured context-specific responses from a small-scale burn in a fragmented, human-influenced landscape, so broader extrapolation should be approached with caution.

Results from this study also suggest the likely benefit of follow-up burning to enhance Dharug desired outcomes and values for *Ngurra*. Follow-up burning may further suppress dominant or invasive flora and trigger regeneration from existing seed banks of fire-dependent species (McKemey et al., 2021). Additionally, burning at varied times of year at different sites could enhance the mosaic of vegetation types and growth stages, as well as refugia and resource availability for fauna (Bird et al., 2018; McKemey et al., 2019). Furthermore, ongoing fire management through Indigenous-led burning within vulnerable urban-bushland interfaces may benefit local communities and ecosystems by reducing fuel loads and decreasing bushfire risks (McKemey et al., 2019; Hoffman et al., 2022). By centring Dharug preferred cultural values and biophysical responses in the monitoring design, this study offers an example for how decolonised fire application and cross-cultural science can operate within highly regulated urban-bushland interfaces. These approaches are becoming increasingly relevant in global efforts to enhance Indigenous stewardship in climate-resilient land care.

5. Conclusions

This study provided rare empirical evidence of the ecological and cultural outcomes of an Indigenous women's-led cultural burn within an urban-bushland interface. Globally, where Indigenous fire practices have been disrupted by colonisation, institutional barriers, and risk-averse policies, these findings demonstrate the potential for Indigenous-led burning to contribute meaningfully to biodiversity conservation, wildfire risk reduction, and the restoration of cultural relationships with Country, even in densely populated landscapes. By showcasing complementary, low-impact approaches to conventional fire management, this work strengthens the case for enabling Indigenous fire stewardship in urban areas as part of broader efforts to support Indigenous inclusion in environmental governance. In the face of escalating climate-driven fire risks, small-scale, low-intensity cultural burning presents an adaptive, place-based strategy to mitigate fire risk while enhancing ecocultural resilience in urban ecosystems. By centring Indigenous leadership and two-way knowledge exchange, this work offers an approach for reimagining fire management through culturally grounded and ecologically informed collaboration.

Declarations

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Competing Interests

The authors declare no competing interests.

Author Contribution

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by GB. The first draft of the manuscript was written by GB and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data Availability

The datasets generated during this study are not publicly available due to cultural and ethical considerations. The project involved co-designed monitoring with Dharug Traditional Owners, whose knowledge and values informed the research. Any requests for access to data should be made in consultation with the Dharug Women's and Allies Cultural Fire Alliance and the corresponding author, and will be considered in line with principles of Indigenous data sovereignty and ethical research practice.

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Figures

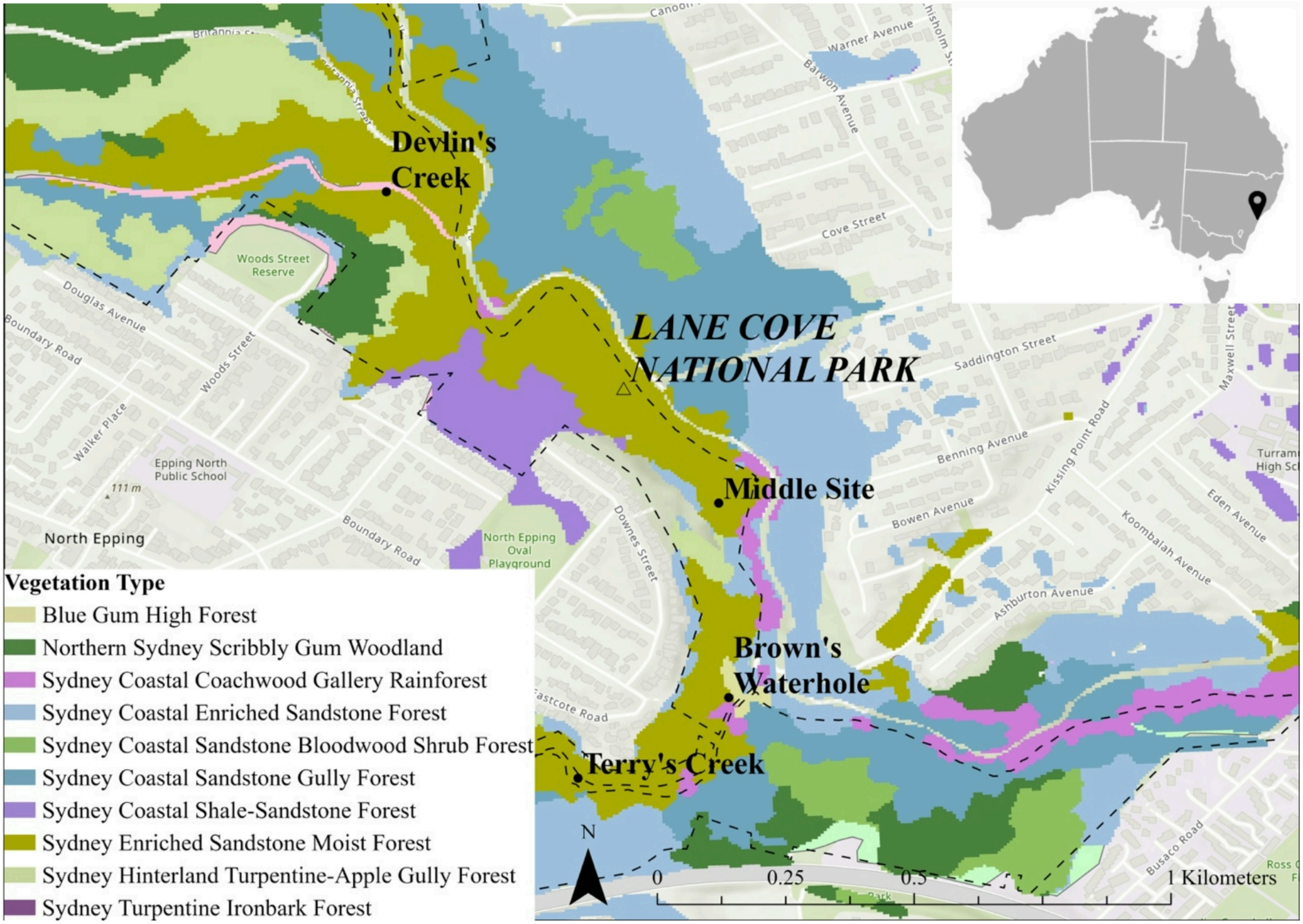

Figure 1

Vegetation map of the impact site (*Bidyiwung Badhu Nuru*/Brown's Waterhole) and control sites (Devlin's Creek, Middle Site, Terry's Creek) surrounding Lane Cove National Park (dashed line), north-west Sydney, Australia. Map created using ArcGIS Pro (Esri, Redlands, CA, USA).

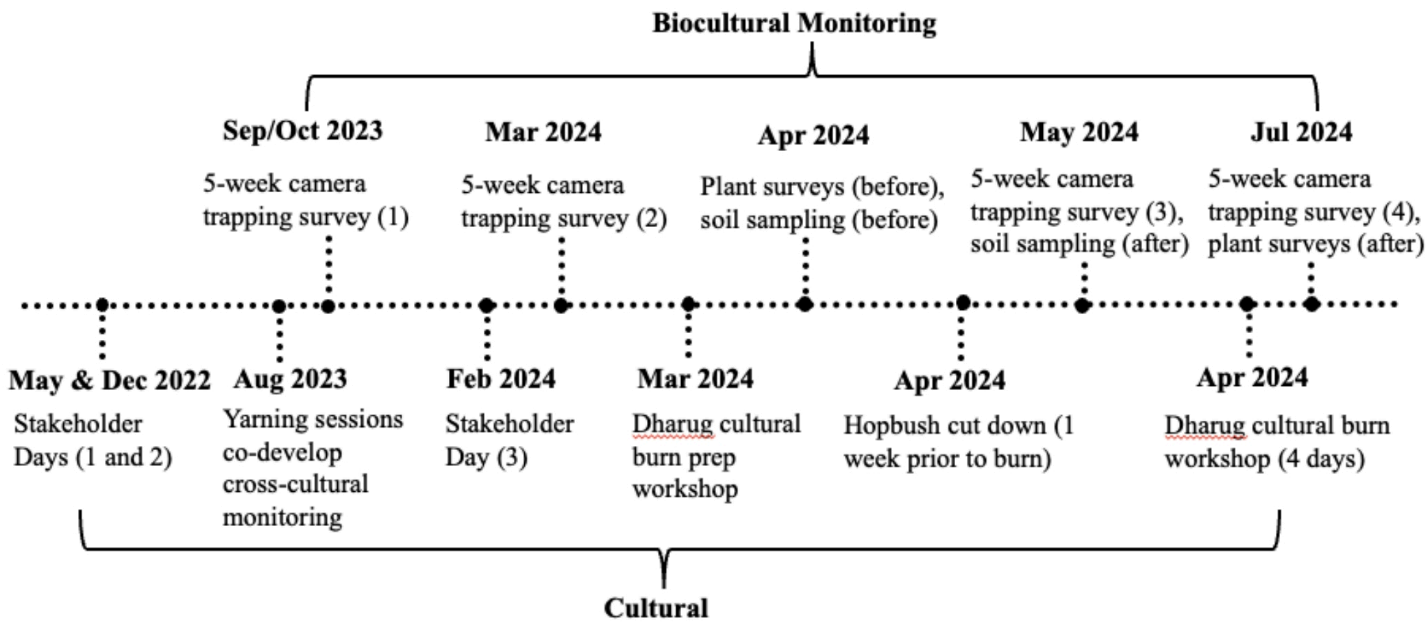

Figure 2

Timeline of biocultural monitoring activities and Dharug *dhiyina*-led cultural workshops associated with the *guwiyang*(fire).

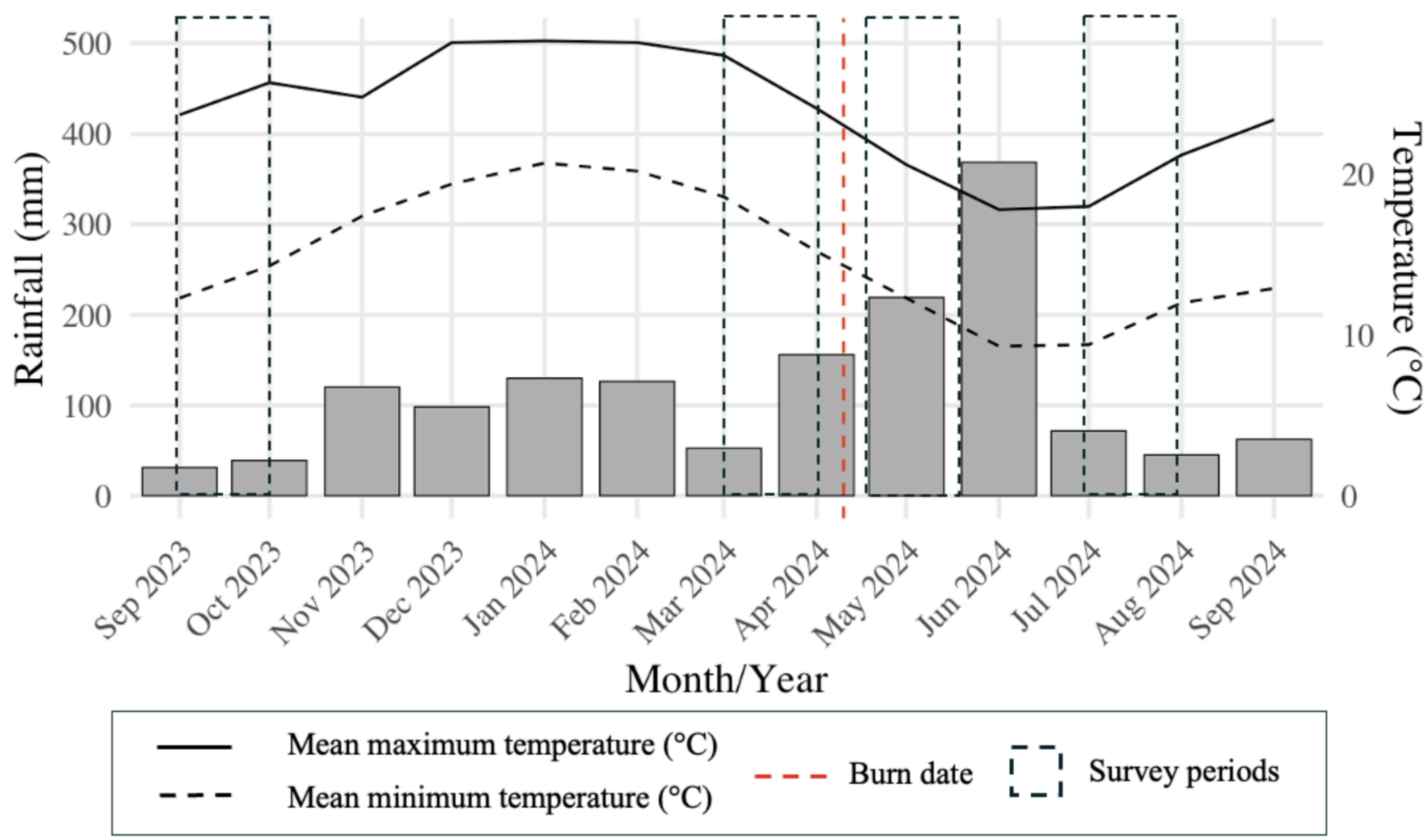

Figure 3

Monthly mean maximum and minimum temperature (°C) and total rainfall (mm) during the monitoring period. Climate data sourced from the Bureau of Meteorology (2025), figure created using R Studio (Version 12.1; R Core Team, 2024).

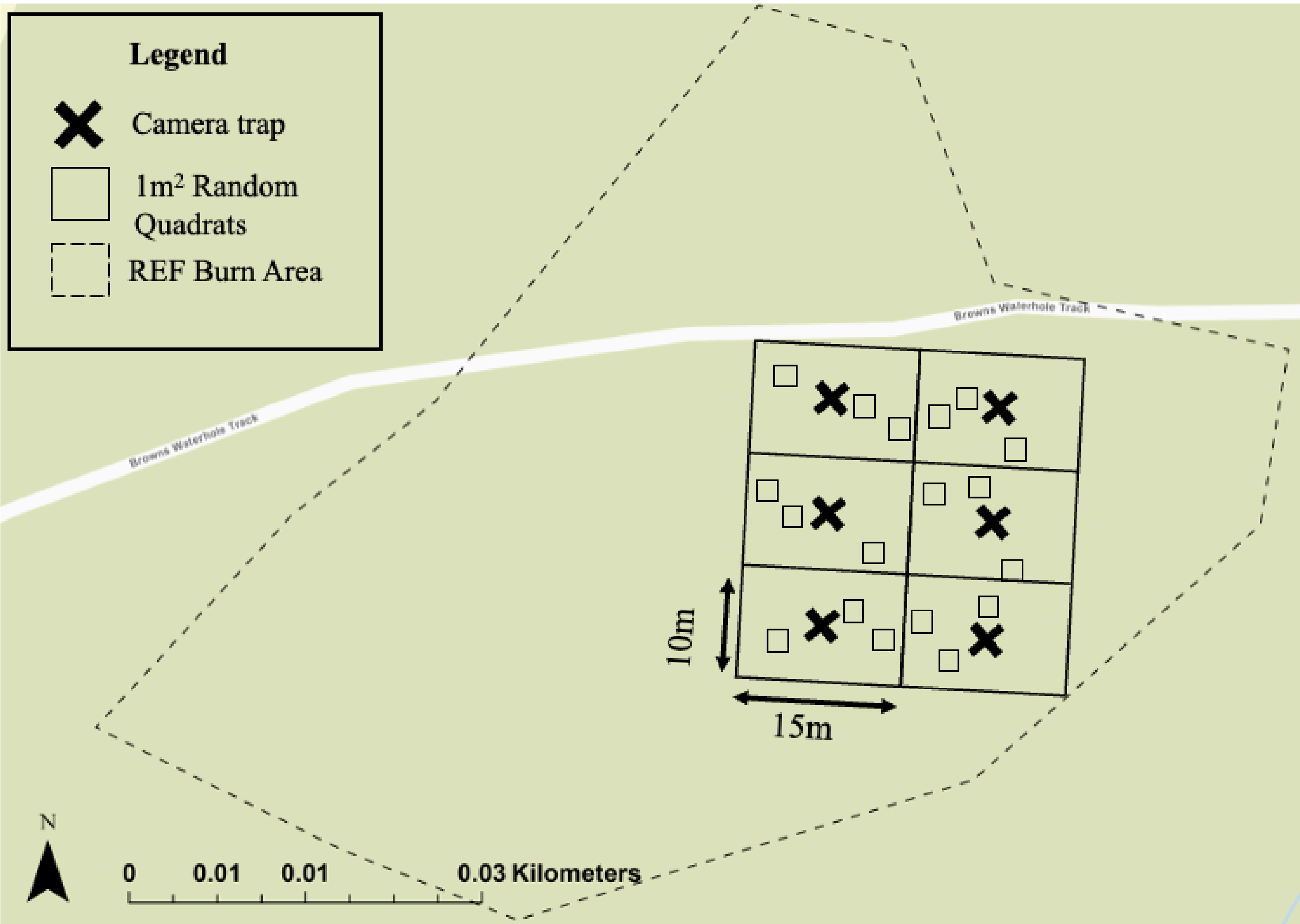

Figure 4

Monitoring layout at the impact (burn) site at *Bidyiwung Badhu Nuru*. The design includes six camera traps (X) and three randomly allocated 1 m² vegetation quadrats per grid cell, mirrored at control sites. Map created using ArcGIS Pro (Esri, Redlands, CA, USA).

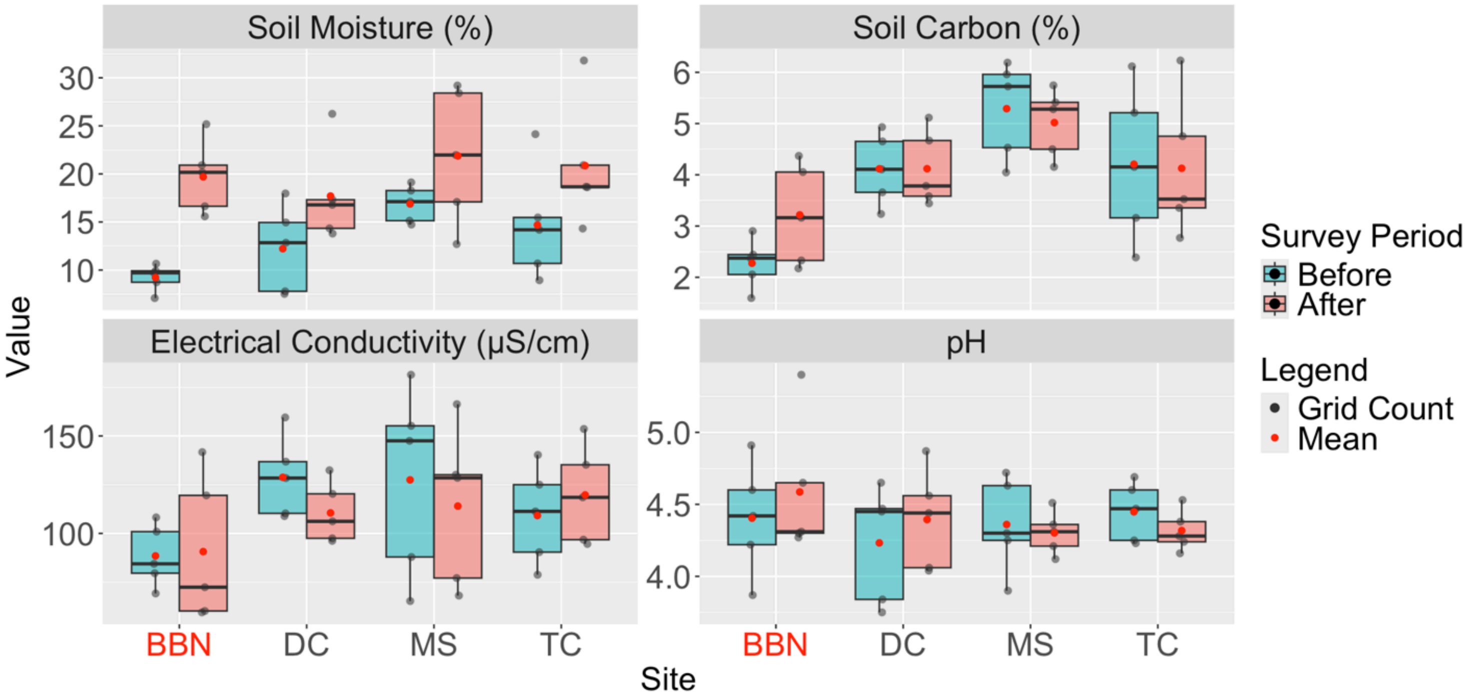

Figure 5

Responses of soil variables at impact and control sites before and after the *guwiyang*, including soil moisture (%), soil carbon (%), electrical conductivity (mS/cm), and pH. Site abbreviations: *Bidyiwung Badhu Nuru* (BBN), Devlin's Creek (DC), Middle Site (MS), and Terry's Creek (TC). Created using R Studio (Version 12.1; R Core Team, 2024).

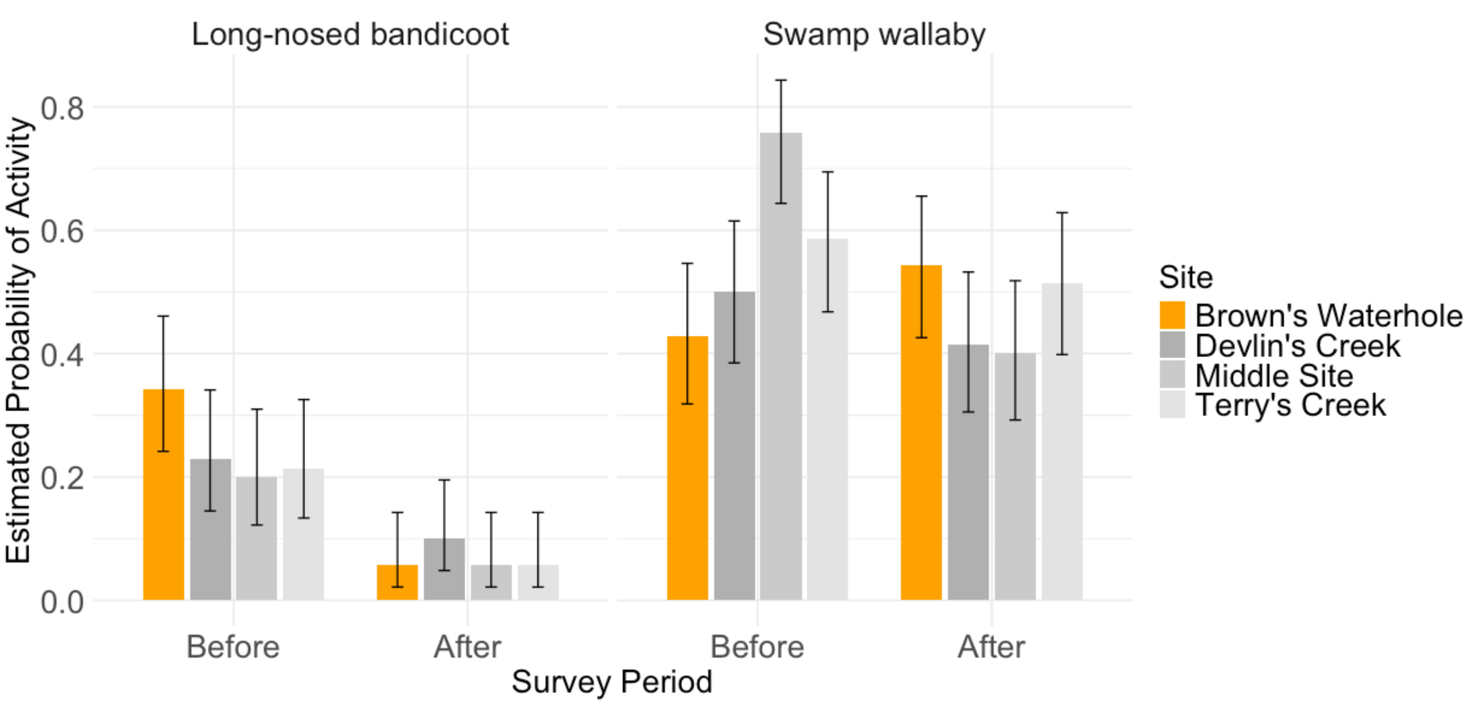

Figure 6

Estimated activity (proportion of days detected) for *Burraga* (Long-nosed bandicoot) and *Bagarayi* (Swamp wallaby) activity, across pooled before and after survey periods at impact and control sites. Prediction probability estimates were obtained from the binomial GLM. Bars show mean predicted probabilities of activity, with 95% confidence intervals. Created using R Studio (Version 12.1; R Core Team, 2024).