Indigenous Knowledge, Aspiration, and Potential Application in Contemporary Fire Mitigation in Southwest Australia

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Abstract
Protection of biodiversity, human assets, and cultural heritage pose significant challenges to contemporary planning of bushfire mitigation activities. Current mitigation approaches are not always appropriate, and mismanagement is a source of distress for Indigenous peoples. Increased understanding of Indigenous fire knowledge and increased Indigenous participation may provide insight into more appropriate and inclusive land management for fire mitigation. We analysed contemporary Noongar and Western fire practitioner approaches within an Indigenous fire knowledge (IFK) framework to explore knowledge and aspirations for small reserves in the Southwest Australian Floristic Region (SWAFR) global biodiversity hotspot. We recorded an extensive knowledge base, characterised by a highly nuanced approach to burning, held by the Noongar coauthors. We explore potential approaches to applying this knowledge to build collaborative fire mitigation strategies with mutually beneficial outcomes for biodiversity, cultural heritage, and human assets.

Keywords Southwest Australian Floristic Region (SWAFR) · Fire · Indigenous fire management · Traditional bio-cultural knowledge · Cultural burning · Fuel reduction burning · Noongar Indigenous Fire Knowledge

Introduction
In contemporary Australian land management, the protection of biodiversity, human assets, and cultural heritage in bushfire (wildfire) mitigation activities pose a significant challenge, especially in the increasing severity and occurrence of large-scale fires (Collins et al., 2021; Fletcher et al., 2021b). Within a broader movement of contemporary recognition and inclusion of Indigenous land management practices, the reintroduction of Indigenous fire knowledge (IFK) and practice for bushfire mitigation has entered the colonial public consciousness (Bennet & Edwards, 2021; Kimmerer & Lake, 2001; McKemey et al., 2020; Robinson et al., 2021). Spatially displaced Indigenous peoples who have been excluded from land management during the colonial era are increasingly gaining access to portions of traditional lands, reinvigorating bio-cultural knowledge, and advocating for better land management practices, especially the use of fire (Cavanagh et al., 2020; Hoffman et al., 2021; Lake & Christianson, 2020; McKemey et al., 2020; Robinson et al., 2021).

IFK is a subset of Indigenous bio-cultural knowledge, defined as “fire-related knowledge, beliefs, and practices that have been developed and applied on specific landscapes for specific purposes by long time inhabitants” (Huffman, 2013). IFK is embedded in socio-cultural systems and forms part of the inextricable spiritual-environmental practice of Indigenous peoples (Ens et al., 2015; Gadgil et al., 1993; Kimmerer & Lake, 2001; McKemey et al., 2020; Pyne, 2016). Despite warnings, (e.g., Agrawal, 2002) against distilling bio-cultural knowledge into transferable, non-contextual classifications, universal knowledge elements contribute to preliminary engagement and exploration of IFK systems to bridge gaps between contemporary land agencies and traditional Indigenous managers (Huffman, 2013). In a 2013 global review, Huffman identified 69 universal elements of IFK while concurrently emphasising such knowledge’s highly differentiated and place-specific nature.

Pre- and early-colonial use of fire by Indigenous Australians to manipulate vegetation is well-documented
The re-introduction of IFK is not a straightforward application of technical knowledge (Hill et al., 2012; Neale et al., 2019; Nikolakis & Roberts, 2020; Petty et al., 2015). The discourse regarding IFK often historicises or traditionalises Indigenous people and knowledge (Christianson, 2015; e.g., see Bowman, 1998). Suggesting IFK as a solution to the shortcomings of current management practices positions IFK as ‘supplemental’ to Western knowledge (Whyte, 2018). Recommendations from recent inquiries into the 2019–2020 Black Summer fires in Australia demonstrate the tension between the distillation of IFK for broader use and inclusion in the agency’s frameworks and the specific nature of the knowledge that loses nuance and meaning when extracted from its context (see for example REC317-4111, Federal 2020 Royal Commission into Black Summer Fires and REC315-3822, NSW 2020 Inquiry into Black Summer Fires). Failure to align with traditional or cultural methods or the extraction of IFK and appropriation into settler frameworks are recognised as risks to collaboration that further contribute to disenfranchisement among Indigenous peoples (Barbour & Schlesinger, 2012; Fache & Moizo, 2015; Neale et al., 2019). Further, diversity in ecological and legislative contexts, the heterogeneous nature of Indigenous peoples and knowledge, and variation in the extent and processes of colonisation across Australia make for diverse IFK and distinct challenges to its application (Huffman, 2013; Neale et al., 2019).

Here we present a specific place-based study in the context of increasing and widespread public interest in Indigenous burning and the expressed desire of the Noongar Traditional Owners for inclusion and improved ecological outcomes of land management for bushfire mitigation. The present research explores the aspirations of the Noongar coauthors (AD, AE, CP, EF, LC, LK, TW) regarding fire management in the study area. IFK relating to those aspirations is recorded and shared where appropriate. We also explore the potential application of aspirations and IFK. This research forms a preliminary step in re-introducing IFK and collaboration between the Noongar Traditional Owners and local government authorities.
Methods

Study Area

This study was conducted in several small local government reserves fringing the Wilson Inlet, in the local government area (LGA) of Denmark, on the SWAFR southern coast (Fig. 1). The reserves are approximately three kilometers south of the town of Denmark and include several Aboriginal cultural heritage sites and culturally essential features (Guilfoyle, 2011). They are small, fragmented, subject to human disturbances, and form a rural–urban interface (Blanchi et al., 2006). Fire records since 1922 indicate the area had not burnt within that period (DBCA, 2020).

The reserves contain 25 vegetation types and at least 159 plant taxa (McQuoid, 2012). Due to the place-specific nature of IFK, we selected four locations as interview sites to represent four key vegetation communities of the Tingle mosaic (Wardell-Johnson & Williams, 1996), including 1. Melaleuca riparian areas, characterised by Melaleuca cuticularis and Taxandria juniperina stands in estuarine lowlands; 2. karri (Eucalyptus diversicolor) forest; 3. granite outcrops; and 4. granite-associated low jarrah (E. marginata) and marri (Cor- ymbia calophylla) forest. The presence of these vegetation communities (McQuoid, 2012) and a priori identified areas of cultural significance informed the selection of interview sites.

The Wilson Inlet is a prominent feature of the eco-cultural landscape for the southern Noongar peoples. The Inlet and Denmark River are a geographical border between Menang Noongar Boodjar and Pibbulmun Noongar Boodjar within the Southern Noongar Wagyl Kaip Indigenous Land Use Agreement (Guilfoyle, 2011; SWALSC, 2020). The Noongar actively use this landscape and continually adapt to new social and environmental contexts. Before this research, the Noongar people expressed determination for involvement in managing the reserves (Guilfoyle, 2011; Mitchell et al., 2008).

Fig. 1 Study reserves (outlined in red) border the Wilson Inlet, approximately 3 km south of Denmark townsite, with vegetation communities included in this study differentiated by colour. Recognised Aboriginal heritage sites are indicated in yellow (DPLH, 2021). The inset map shows the SWAFR (Gioia & Hopper, 2017) and contemporary Noongar Indigenous Land Use Agreements (ILUAs) (National Native Title Tribunal, 2021), including the Southern Noongar Wagyl Kaip ILUA in which this research was conducted. Traditional Noongar Boodjar roughly aligns with the border of the SWAFR; contemporary ILUAs approximate this.
Study Participants

Study participants belonged to one of three groups (Table 1). The Noongar authors were identified through relationships with coauthors SH and AL and informed by the Aboriginal Cultural Heritage Management Plan for the Southern Section of Kwoorabup Beelia (Guilfoyle, 2011). Further Noongar authors were identified through a snowball sampling method. Participants with specific traits (i.e., membership in a research participant group) are identified through referral by existing participants (Liamputtong, 2010, pp. 69–71). Only Menang and Goreng Noongar people collaborated in this research., Pibbulmun and Wadandi Noongar Traditional Owners were invited but unable to collaborate due to circumstances unrelated to this study. Participating fire practitioners and representatives of two community groups with active roles in reserve management were identified through the Shire of Denmark Fire Mitigation Coordinator, also using a snowball method.

Data Collection

A series of semi-structured interviews were held between October 2020 and March 2021, under UWA Human Ethics approval RA/4/20/6165. Seven interviews were conducted ‘on Country’ (i.e., at a location on traditional homelands) at each study site with the Noongar authors to address research questions concerning their aspirations, knowledge, and the potential for its application. Each family visited sites separately, a research practice already established between coauthors (AL and SH) and Elders (Lullfitz et al., 2021). Where appropriate, the presence of a younger Noongar family member was encouraged to create opportunities for intergenerational knowledge transfer. Participants who were not otherwise reimbursed for their time received payment.

To address IFK application research questions, semi-structured interviews were conducted with fire practitioners and community group representatives. Five fire practitioners were interviewed on Country across three interviews. One of the four community group representatives was interviewed on Country, while others were interviewed offsite in a second group interview.

The interviews followed a yarning methodology, in which members speak, reflect, and respond to each other in a collaborative conversation to avoid extractive research (Bessarab & Ngandu, 2010; Buchanan et al., 2019). A list of key discussion points informed open-ended questions across all interviews to ensure standardisation of topics while accounting for varied worldviews. All responses were recorded in audio or video with participants’ permission and transcribed. Each participant reviewed a transcribed record to ensure accuracy. All intellectual property shared in interviews remains with the relevant participant.

After interviews, two workshops were held to discuss the potential application of the Noongar IFK. At a workshop on 22/04/2021, the Noongar authors met to discuss their aspirations and knowledge shared in the interviews. In this workshop, a document outlining specific recommendations to the LGA for the Noongar burning practice was authored by the Noongar Elders. A workshop on 26/05/2021 on Country included representatives from the study’s participant groups. Each workshop was recorded and transcribed.

To assist in discussions of potential application, vegetation community characteristics, recorded in a 2012 study (McQuoid, 2012), were ground-truthed using relevé methodology (EPA, 2016) to record environmental characteristics and dominant vegetation and structure. For each vegetation community, a fuel hazard assessment was conducted using a standard method used in the LGA’s current fire practice (DENR, 2011 [Gov. SA. 2012]).

Data Analysis and Review

Transcribed interview statements from each participant were coded into primary and secondary codes (Saldaña, 2009) in NVivo 12 software (QSR International, 1999), using a framework derived from the 69 universal elements of Indigenous fire knowledge identified by Huffman (2013). The procedure allowed fire knowledge systems participants referred to in interviews to be analysed against a standardised, Indigenous knowledge-based framework. Direct quotes from study participants have been provided as supplementary material to include specific and localised IFK otherwise not captured within a universal framework (Agrawal, 2002; Huffman, 2013).

Statements were first coded at a low resolution, using the seven categories of universal elements of fire knowledge defined by Huffman (2013): These are 1. Fire behaviour; 2. Fire effects; 3. Fire governance and other social aspects; 4. Fire operations; 5. Geology, topography, and soil; 6. Vegetation and fuel; and 7. Weather. These categories were then
used to code the data at a higher resolution, using all 69 elements described by Huffman (2013). Knowledge elements from Huffman’s framework are italicised throughout this paper. For example, the following statement was coded to flame height; season, onset or end of the rainy or dry season; and rate of spread:

“As a kid, my family used to burn off, just before, when the autumn rains came in, the first two heavy rains of the year... But we were doing small burns, slow burns. You don’t do high burns, it’s not a fire thing anymore.” (Noongar Elder, 16 October 2020)

To minimise possible bias relating to interview length and/or the number of participants in each group, a table of the standardised proportion of total statements relating to each code for each participant was constructed.

All participants’ tabulated statements were analysed to identify differences between groups. Differences in participants’ statements were calculated using Euclidean distance, visualised with non-metric multi-dimensional scaling (nMDS), and analysed using Adonis and ANOSIM (Bataille et al., 2020; Lullfitz et al., 2021). SIMPER and IndVal analyses were applied to identify uniquely common elements among a group (i.e., common within a group and uncommon across other groups) and elements driving differences between group comparisons. Participants with less than n = 10 statements regarding fire were excluded from the comparative analysis.

Noongar statements that related to one of the four identified vegetation communities (melaleuca riparian, karri forest, granite outcrop, and granite associated jarrah-marri forest) were coded accordingly. These were tabulated to produce a count of statements referring to each code for all participants and vegetation types. This was visualised using (nMDS) and analysed for differences using Adonis and ANOSIM, based on Bray–Curtis distances in the Vegan package (Oksanen et al., 2019) for R software (R Core Team, 2017). Results and methodology were discussed and reviewed by the Noongar participants in a workshop held at UWA Albany on 22/04/2021.

Results

Semi-structured interviews returned 1298 fire-related statements from 19 participants, comprising of 803 statements from eight Noongar participants, 107 from four participants representing community groups, and 388 statements from seven fire practitioners.

Noongar Aspirations in Contemporary Fire Management

All the Noongar authors expressed an aspiration for better management of their Country. They all considered the reserves to be currently overgrown and stated that this would not have occurred if under traditional Noongar management. For example, concerning specific conditions at one site:

“This undergrowth is years old. Noongars only let it get to two years, and then they’ll come back and burn it again. There’s a lot of difference.” (Noongar Elder, 16 February 2021)

While other participants did not echo such frequency of burnings, the issue of overgrowth was expressed to be bad for both people and ecological health by seven Noongar participants, and all suggested that better management, including the use of fire, could remedy this, e.g.:

“I think that’s what our goal and aim needs to be: bringing people out into the environment and enjoying it for what it is, and also protecting and preserving [the environment].” (Noongar Elder, 3 December 2020)

An aspiration and willingness to be involved and general positivity regarding the inclusion of Noongar IFK in fire mitigation in Denmark was expressed, e.g.:

“It’s about time that they sat down and listen to Indigenous people, people in the know, people that know how to treat it [the land]. This [current reserve ecosystem state] is a travesty.” (Noongar Elder, 16 October 2020)

It was agreed by all Noongar participants that the highest priority aspiration, and a requirement, for Noongar burning in the Denmark LGA is Noongar governance and that any burning considered ‘cultural’ or ‘traditional’ must come under the guidance of the Noongar Elders. Seven Noongar Elders collectively expressed through interviews and workshops the importance of the involvement of the Noongar people in all aspects of land management and that, in turn, would provide socio-cultural benefits to the Noongar people, e.g.:

“And it is better for their [younger Noongar people’s] health, for their wellbeing, to know how to manage the land, how to care for the land...I think it [caring for Country] is important and I think it gives them a chance to be Noongars.” (Noongar Elder, 4 March 2021)
Noongar Fire Knowledge

Across the 803 statements by Noongar participants regarding fire, fifty-nine (85.5%) of Huffman's (2013) universal knowledge elements of IFK were addressed. A summary and corresponding example of statements relating to the ten most frequently addressed elements (each > 50 statements) is provided in Table 2 (see supplementary material for all elements). These were: fire effects on vegetation; fire placement; land stewardship, care, cleaning up country, controlling space; landscape pattern, patch size; fuel load; control; site preparation; vegetation type; fuel composition/species; and fuel consumption, degree, speed.

Considerable nuance was observed within each knowledge element. For example, fire effects on vegetation contained statements concerning the benefits of fire for “cleaning up” (Noongar Elder, 16 October 2020) and “helping the growth” of vegetation (Noongar Elder, 4 March 2021), in reference to general vegetation and specific site features or species. It also included statements on the destructive effect of incorrect fire. Statements concerning land stewardship, care, cleaning up country, controlling space included discussion of traditional people’s close knowledge and stewardship of their Country, the importance of fire within Noongar socio-cultural systems and identity, and contemporary “cultural obligation” (Noongar Elder, 24 November 2020) and socio-cultural benefits of caring for Country.

It was expressed by Noongar participants that the current level of vegetation at study sites that has the potential to fuel bushfires is of concern and that this would not have accumulated under traditional Noongar management. It was expressed that burning the landscape in its present state would mean applying Noongar IFK to new circumstances, e.g.:

“I think the only way you can do it is doing small patches” (Noongar Elder, 25 November 2020).

Four participants used “cold” or “cool” to describe the ideal fire intensity, heat output. All Noongar participants emphasised that desired fire behaviour kept flame height low, away from the vegetation canopy, e.g.:

“Most of our fires were ground cover” (Noongar Elder, 16 February 2021).

These specific attributes were discussed in reference to the ability to control fire, as is considered paramount to a successful application, e.g.:

“Fire is good as long as you can control it” (Noongar Elder, 25 November 2020).

Five Noongar participants expressed a qualitative distinction between the four vegetation communities represented in the study. The influence of vegetation community type on fire application was common among responses (n = 54 statements). However, the necessity to possess specific knowledge of the area, regardless of vegetation community type, was a consistent response from all Noongar participants. They expressed that close and careful monitoring of vegetation/fuel and weather conditions should precede the application of fire to achieve desired fire behaviour. All Noongar participants referenced fuel load, vegetation type, and planning, monitoring conditions. Differences in statement knowledge elements between granite outcrop and karri forest (p < 0.05) and granite outcrop and melaleuca (riparian) (p < 0.05) comparisons were identified through pairwise comparisons and nMDS visualisation (Fig. 2). Summaries of knowledge relating to specific vegetation types are presented in Table 3. Smaller, less ubiquitous, and more targeted use of fire on granite was highlighted as a significant difference from the other vegetation types. Small, low, and smoky fires were suggested for the forest and wooded areas.

Potential IFK Application

Similarities

Analysis of interview statements through Huffman’s (2013) universal knowledge elements showed similarities and differences between the three participant groups. Noongar participants referred to more of Huffman’s (2013) 69 universal knowledge elements (n = 59, 85.5%) than fire practitioners (n = 48, 69.6%) or community group representatives (n = 35, 50.7%). Frequently mentioned and indicator elements (from IndVal analysis) for each group are displayed in (Fig. 3).

Elements addressed by participants in all groups were landscape pattern, patch size (all relating to using a
Table 2  Frequently addressed Noongar knowledge elements and examples. This study used 69 knowledge elements identified by Huffman (2013) to systematically analyse Noongar IFK. Seven categories of elements were used as level one codes, listed here under “Knowledge element categories (Level one codes).” A summary of responses to these seven is provided in italics under the category heading. Frequent knowledge elements (the top ten referred to in interviews, referenced in > 6% of statements) are shown next to their related category. For each of these prominent elements, a summary and example are provided. The number of statements coded to each category and element is provided in brackets ()

| Knowledge element categories (Level one codes) | Frequently addressed knowledge elements (ten most referred to in interviews) | Summary of statements referencing frequent knowledge element identified | Example statements coded to frequent knowledge elements |
|------------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------------------------|-------------------------------------------------------|
| Fire Operations (298)                           | Fire placement (96)                                                       | Strategic and specific placement of fire for predicted outcomes. Mostly near campsites, on granites for manufacturing or near specific food or medicine plants, avoiding mature trees | “They [older, deceased relatives of Elders interviewed] would know where all these medicinal plants are, and trees, and they would go there to specifically burn the undergrowth and make sure that it’s cleared, protected and taken care of.” |
|                                                | Pattern, patch size (86)                                                  | Burning in patches as assumed approach, patch size depends on vegetation and fuel characteristics | “They [older relatives] would only do very small patches at a time.” |
|                                                | Site preparation (59)                                                    | Site preparation is essential for burning safely, especially close to camps and other vital assets, such as mature trees | “I would burn this…in pieces, like patchwork.” |
|                                                | Control (62)                                                             | Control is critical to achieving the desired fire behaviour—control as a definitive factor of Noongar burning | “And bigger trees with bark, [they’d clear in] a circle around it, so that when they burn it, it wouldn’t catch alight.” |
|                                                | Fuel load (72)                                                           | Fuel load determines how a place may be burnt. Existing fuel loads at study sites were higher than they would be under traditional Noongar management | “Fire is good as long as you can control it.” |
| Vegetation, Fuels (179)                         | Vegetation type (54)                                                    | Recognition of differences in vegetation types. Less likely to burn in melaleuca riparian and on granites, more likely in forested areas | “I think it was a more conservative and considerate way of burning, that’s my view of the way that the old people used to do it.” |
| Differences in vegetation inform different fire applications | Composition & species (54)                                              | Many specific species were mentioned regarding how they burn or their need for/response to fire—special attention was paid to resource species. Introduced species have changed fuel composition | “What we are looking at here is all this overgrowth from many, many years, which in our cultural history we wouldn’t have.” |
| Fire Effects (175)                              | Fire effects on vegetation (126)                                         | Fire encourages regeneration for animal feed, the health of plants, and increased resources. It helps to clear overgrown areas, allowing access and improving vegetation health and aesthetic value | “It’s [the granite] not as overgrown as down there [the forest], so down there you’d have to be really careful.” |
| Fire clears undergrowth and encourages regeneration, increasing resources. Not burning or burning incorrectly carries consequences | Land stewardship (87)                                                  | Fire is a critical tool in the land care toolbox. It helps to care for vegetation and campsites and is a symbol of home. It is rooted within cultural rites of caring for the country | “Because if it gets in these paperbarks [M. cuticularis], it won’t burn down here, it will burn up top when it gets those leaves, it will go straight along those leaves.” |
| Fire Governance (146)                           |                                                                           |                                                                      | “You’d make sure that [M. cuticularis] was protected because that’s water there, and there may be food plants there.” |
| Fire is embedded in cultural obligations and controlled through social structures |                                                                           |                                                                      | “All species need burning, that’s to help the growth.” |
| Noongar governance of contemporary burning       |                                                                           |                                                                      | “From an Aboriginal person’s perspective, this isn’t any good unless it’s been burnt. Like my dad used to say, ‘fire fixes everything.’” |
|                                               |                                                                           |                                                                      | “It was like this collaboration with nature, or partnership with the bush.” |
|                                               |                                                                           |                                                                      | “And it’s also, fire we call it ‘kaarl’, but it’s also home, ‘kaarl’ is our home fire.” |
‘patchwork’ approach, fuel composition and species, vegetation type, fire placement, and fire effects on vegetation. The community group and Noongar participants addressed the elements of land stewardship, care, cleaning up country, controlling space. Operational elements, including fuel load, fuel consumption and site preparation were addressed by Noongar and fire practitioner participants. Fire practitioners’ and community group participants shared a focus on elements burning regulated by the government, authority to burn, calculated through IndVal analysis, and the ten most referenced elements for each group.

**Differences**

Statistical analyses confirmed the group-based difference between fire practitioners and Noongar participants based on the knowledge elements discussed by each group (displayed in Fig. 4) (ADONIS p < 0.001 and ANOSIM p < 0.001). Pairwise comparisons identified a significant difference between Noongar and fire practitioner (p < 0.05) and Noongar and community group participants (p < 0.05). IndVal analysis showed more indicator knowledge elements for Noongar responses (n = 11) than other participant groups (n = 1, n = 0).

Differences were observed within each element across the groups. For example, all participants discussed landscape pattern, patch size. For non-Noongar participants, this was often in speculative discussion about their expectation of Noongar burning. Fire practitioners expressed patchwork burning as a neat grid and a procedure that helps to achieve controlled burns in a high fuel area. At the same time, Noongar participants suggested patches to control fire in reserves that they considered overgrown. They further recognised their use to enhance resources, burning sequentially to ensure animal access to food and shelter. Both fire practitioners and Noongar participants noted that large trees should have vegetation cleared away from their bases. For some Noongar participants, this related to totemic obligations and the rights of trees as spiritual beings, which were not of concern to fire practitioners.

For fire practitioner participants, the elements of fire intensity and risk, danger and destructive potential were more common compared to other participant groups (determined through IndVal analysis). Risk and the use of fire to ‘clean up’ areas were well understood by Noongar participants but were not the only prominent concern. The focus of Noongar discussions fell on knowledge elements that work to avoid risk (e.g., control, site preparation, wind speed, and wind direction). The Elders identified the need to remove excess fuel before burning to avoid undesired fire behaviour. For example, one Elder expressed: “If there’s too much fuel, then it’s going to go up” (Noongar Elder, 4 March 2021).
Inherent understanding of fire was different between the study groups. Comfort and ease were displayed with acknowledgment of associated risks in conversations with the Noongar authors. One Noongar participant pointed out that the Noongar word, *kaarl*, is used both for fire and home. Another participant used “burning track” as synonymous with “walking track” and is the area one is responsible for managing (Noongar author, 23 February 2021). In contrast, conversations with non-Noongar participants were characterised by discomfort, discussions of risk and unknowns, and a desire to learn more about fire behaviour and ecology. Fires were positioned as inherently out of control in these conversations.

**Potential Application**

All participants at workshop meetings observed a positive approach to partnership and collaboration in fire mitigation. Workshop participants shared the view that study reserves needed some mitigation action and supported collaboration on the application of fire in the study reserves. Hesitation was expressed due to the new and experimental nature of the collaborative project: “the biggest hurdle is that no one is wanting to pull the trigger” (fire practitioner, 26 May 2021). The perceived overgrown nature of the reserves chosen for this study, along with forming a rural–urban interface and the fragile ecology of the reserves, was also of concern to participants. All Noongar participants were explicit that remedying agency mismanagement of the reserves was not their responsibility.

“But before that [re-introducing cultural burning], we are trying to fix something here that is broken, so maybe their [fire practitioners’] science is about creating fire breaks first and then later on let the old Noongars strike the match and let it burn.” (Noongar Elder, 24 November 2020).

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**Fig. 2** On-county semi-structured interviews were conducted with Noongar co-authors across the vegetation communities included in the study. These are (a) melaleuca riparian, (b) karri forest, (c) granite outcrops, and (d) granite-associated jarrah-marri forest.
| Granite Outcrops on Ocbils (114) | Granite Outcrops on Ocbils (114) |
|---------------------------------|---------------------------------|
| Vegetation structure: Low kwongan in shallow soils and Borya herb fields with high number of annuals | Vegetation structure: Low kwongan in shallow soils and Borya herb fields with high number of annuals |
| Characteristic species: Borya nitida, B. spherocephala, Lepidosperma gnumala, Andersonia sprengeloides, Kunzea recurva, Agonis theiformis | Characteristic species: Borya nitida, B. spherocephala, Lepidosperma gnumala, Andersonia sprengeloides, Kunzea recurva, Agonis theiformis |
| Fuel hazard rating: Low to medium | Fuel hazard rating: Low to medium |
| Categories (level one codes) | Summary of statements relating to granite outcrops for each category | Example statements |
| Fire Behaviour (7) | Granites act as a firebreak for burning nearby areas. Very small, controlled incidents of fire on a rock surface | “There’d be very little burn here because there’s very little undergrowth. The fire wouldn’t be fierce enough to reach that [granite].” |
| Fire Effects (22) | Fire cracks the granite and is used to make and ‘clean up’ around gnamma and lizard homes. Clearing too much vegetation exposes important sites and impacts habitat | “[They would use fire] only to crack it, to crack it and break it.” |
| Fire Governance (13) | The high cultural importance of granite and contemporary heritage values must be considered when burning. Granites are places of teaching and tool making, no camping on granites. Little recollection of burning on a rock surface, though cared for regularly as part of the Country | “Those granite rocks always had some spiritual meaning connected to them.” |
| Fire Operations (19) | Burn small areas around the granite, using the rock as a fire break, then fire specific points on the rock for clearing and making gnamma or lizard homes | “We would only do small patches as compared to doing quite a lot of burning there on the river.” |
| Geology, Topography, Soil (17) | Granite can explode in a hot fire, but outcrops are not at risk in cool fires. Granite outcrops often on high ground: act as a look out, fire burns quickly up hills. Sandy soils around granite have different vegetation | “We need to take into consideration the layout of the landscape.” |
| Vegetation, Fuels (18) | Comparatively, little vegetation means less need to burn and less threat from uncontrolled fire—differences in vegetation, shallow-rooted plants, and high incidence of culturally essential and refugial species recognised by participants. Fauna habitat values of granite vegetation recognised. Vegetation surrounding may have been cleared for visibility or left to conceal culturally essential places | “Fire makes granite fire off like bullets, explode.” |
| Weather (5) | Climatic change may increase risks to granite, including higher temperatures and drier periods. The wind is used to direct flames as desired | “These things here [Borya herbfields], you wouldn’t burn these, simply for if there’s no lizard trap around well then, they’re the place where the lizards would be.” |
| Karri Forest on Yodfels (94) | Karri Forest on Yodfels (94) |
| Vegetation structure: Tall forest, dense mid- and understorey | Vegetation structure: Tall forest, dense mid- and understorey |
| Characteristic species: E. diversicolor, Agonis flexuosa, Corymbia calophylla, Trymallium odoratissimum, Chorisia joergensenii, Callistachys lanceolata, Anigozanthos flavidus, Pteridium esculentum, Billardiera fusiformis, Hardenbergia comptonia and Opercularia hispidula | Characteristic species: E. diversicolor, Agonis flexuosa, Corymbia calophylla, Trymallium odoratissimum, Chorisia joergensenii, Callistachys lanceolata, Anigozanthos flavidus, Pteridium esculentum, Billardiera fusiformis, Hardenbergia comptonia and Opercularia hispidula |
| Fuel hazard rating: Extreme | Fuel hazard rating: Extreme |
| Categories (level one codes) | Summary of statements relating to karri forest for each level one code | Example statements |
| Fire Behaviour (13) | Cool, smoky ground fires with a high degree of patchiness. Potential for smouldering and/or entering the canopy | “They [fires] would be all down low because if they got up around your head then they’d just climb up into the trees.” |
| Fire Effects (10) | Correctly applied fire is beneficial for plants and soils The fire was used to clean out undergrowth to make the area habitable and/or traversable | “As well as taking away the forest floor and undergrowth, it’s actually putting some chemicals and materials back into the soil.” |
Table 3 (continued)

| Granite Outcrops on Ocbils (114) |
|----------------------------------|
| **Fire Governance (4)** | Karri is an unlikely place for camping; it is considered home to spirits. Karri marks a geographical border between Menang and Pibbulmun Country. |
| **Fire Operations (31)** | Very small, controlled fires in a system of continuous management. Patchwork approach, using firebreaks. Clear around trees to avoid flames reaching the canopy. |
| **Geology, Topography, Soil (6)** | Forest soil can be moist; some moisture is good for burning. Camp in areas where Karri begins in the study sites. |
| **Vegetation, Fuels (24)** | Undergrowth/fuel density, structure, and moisture influence operations and differ in the forest from other communities. High fuel loads now observed in karri forest are considered overgrown and would not occur under traditional Noongar management. |
| **Weather (5)** | Beware of the swirling wind underneath the canopy. Lightning as a source of fire in the forest. |

**Jarrah-Marri Forest associated with granite outcrops on Ocbils (74)**

Vegetation structure: Low, open kwongan marri forest in shallow soils near granite outcrops

Characteristic species: A. flexuosa, C. calophylla, E. marginata, Hakea nitida, Acacia saligna, Xanthorrhoea preissii, M. cuticularis

Fuel hazard rating: Very high

| Categories (level one codes) | Summary of statements relating to jarrah-marri forest for each level one code | Example statements |
|-----------------------------|-------------------------------------------------------------------------|-------------------|
| **Fire Behaviour (13)** | Low, slow, cool fires. Use granite for natural extinguishment. Potential to be hotter than forest or wetland fires and potential for extended smouldering. |
| **Fire Effects (16)** | The fire is used to ‘clean up’ vegetation, remove undergrowth, and encourage regeneration. Areas around granite are cleared for access and safety. |
| **Fire Governance (9)** | Burning around granites is part of caring for and protecting them. The presence of medicine and other vital plants warrants special attention. Potential to expose important sites through too much clearing; some features should be excluded from fire. |
| **Fire Operations (34)** | Clearing undergrowth around granites in associated vegetation rather than on rock. Continuous management through thinning undergrowth in small patches over time. Start with the least dense patches first, use firebreaks, and maintain close control. Plants should not be killed, protect marri trees. |
| **Geology, Topography, Soil (8)** | Sandy soils are drier due to sun exposure. Often on or near a slope, fire moves faster uphill. Granite rocks act as a firebreak. Granite peaks are lookout sites, clear surrounding vegetation for visibility. |
| **Vegetation, Fuels (24)** | Recognition of differences in vegetation, more medicine, and food plants. Vegetation surrounding may have been cleared for visibility or left for concealment of essential places: high fuel loads and drier vegetation. |

Features: “We never used to camp in tall timber.”

“Very small, controlled fires in a system of continuous management.”

“This is years and years of undergrowth. Years and years.”

“This is all cold burns so that it’s done accordingly and guided and controlled accordingly.”

“Nothing we would actually pull out what needs to be done.”

“It would burn slowly yeah, some of it would burn.”

“If this was in our time, in traditional times, it would be like a park.”

“If we had to camp, we’d camp right back up that way.”

“If this was in our time, in traditional times, it would be like a park.”

“Karri is known for flames going up, most of the bark has been shed at this time of year now.”

“Even in these big trees, wind is the main factor.”

“Beware of the swirling wind underneath the canopy. Lightning as a source of fire in the forest.”

“Even if you were in the forest, you’d have a clear run.”

“Just looking at all this environment so far, there’s some very good bush medicine here.”

“It burning] all depends on how thick it is.”

“Was a bit of bush and grass trees, looks like it’s about time that some of them needed some fire, just to get rid of their dresses and clean around underneath them.”

“Double edge sword.”

“A sort of polka dot action… In thick bush, you’d be better off to do it within the radius of these bushes here, so you could put it out and go light another over there and another one over there.”

“The whole lot would have been cleared so they can see the skyline and see where that mob is moving by the fires.”
Table 3 (continued)

Granite Outcrops on Ochils (114)

| Weather (11) | Weather conditions important due to potential danger. Close attention paid to wind, use wind to direct fire | “[Burn] with that right wind because it’s on a bit of a hill.” |

Melaleuca Wetlands – riparian on Yodfel alluvial flats (65)

Vegetation structure: Melaleuca and Taxandria stands, seasonally wet, with dense sedge and reed understorey

Characteristic species: *M. cuticularis*, *Taxandria Junipera*, *Leptosperma gladiatum*, *Ficinia nodosa*

Fuel hazard rating: Extreme

| Categories (level one codes) | Summary of statements relating to melaleuca wetlands for each level one code | Example statements |
|-----------------------------|---------------------------------------------------------------------------------|-------------------|
| Fire Behaviour (15) | Low, cool, slow, smoky fires with high patchiness and low intensity. Natural extinguishment through moisture, the potential for smouldering | “It helps if you’ve got damp underground… so going through and burning areas that [the fire] just goes over the top of them.” |
| Fire Effects (16) | The fire was used to clear the area for safe access. Ash and charcoal are considered cleansing for water sources | “To make sure that the environment is protected for their safety … as well as making sure that the fuel load is … taken care of.” |
| Fire Governance (6) | Camping usually occurs ~ 100 m away from the edge of water sources but needs clearing for access and safety | “My own family never used to camp on the water's edge, they used to camp back further.” |
| Fire Operations (27) | Manual clearing around trees, especially before the fire | “I think you said something about what wouldn’t I do… the water tree, *M. cuticularis* well you’d make sure that was protected.” |
| Geology, Topography, Soil (11) | Soil moisture provides for natural extinguishment and helps to prevent killing plants at roots. Moisture can cause fire to smoulder for long periods | “The water is the means of it [the fire] going away, it goes to the water and then fizzles out.” |
| Vegetation, Fuels (24) | Melaleuca is fire-resistant due to moisture in the bark but flammable (‘like petrol’) canopy | “I’d leave this [riparian zone] as a barrier here, for windbreak, erosion.” |
| | Critical ecological functions of riparian vegetation recognised, meaning judicious fire application is necessary. The fire should not be hot enough to kill plants | “If it gets in these paperbarks, it won’t burn down here it will burn up top when it gets those leaves, it will go straight along those leaves.” |
| | Reeds/rushes are more manageable to clear with fire than the fuels and weeds that exist now but are more demanding than clearing the forest floor. Existing vegetation is overgrown | “Remember we were maintaining so it was more or less cleared and our footprints would have stopped any growth like that.” |
| Weather (5) | The wind is a significant factor due to its proximity to the water and needs low or no winds | “You’ve got to wait for that wind behind you… if the wind is blowing towards the water, light it up.” |
Further, planning and legislative requirements, including burning permits, were a hurdle to applying Noongar IFK in the area. Fuel load surveys across the four sites showed that all but the granite outcrop sites had very high to extreme fuel loads.

Discussion

Aspirations

Through this study, the Noongar Elders have voiced their aspirations regarding fire management in a step towards reintroducing Noongar IFK in a highly colonised area, where, to date, discussions of IFK have excluded the Noongar people (Nyquist, 2019). Three fundamental aspirations identified were better fire management, the establishment of Noongar governance, and systematic inclusion of the Noongar people, which point to a desire for entwined ecological and socio-cultural benefits.

Burning is intrinsic to Noongar life, or as one Noongar author expressed, a “natural blackfella thing to do” (Noongar Elder, 16 October 2020), and is rooted in a reciprocal relationship with landscapes that is common in Indigenous cultures (Eriksen & Hankins, 2014; Gadgil et al., 1993; Wooltorton et al., 2018). Another participant expressed: “I remember my mother saying to me, ‘this is your country’ and…what she meant was ‘this is your responsibility’” (Noongar Elder, 24 November 2020). Such a reciprocal relationship to traditional land informs IFK and the socio-cultural benefits of existing Indigenous and collaborative burning programs (Altman & Kerins, 2012; Kimmerer & Lake, 2001; McKemey et al., 2020).

Fig. 3 nMDS of Noongar participant statements coded to fire knowledge elements (Huffman, 2013) for vegetation type. Each point indicates one participant’s statements coded to a particular vegetation type and Huffman’s (2013) universal elements of IFK. Grouping of statements regarding granite (orange) and karri forest (green) are observable. Pairwise comparisons determined that these are statistically different. Granite statements also differed to statements for melaleuca stands (grey) in pairwise comparison.
Mismanagement of land and misuse of fire and destructive fires are considered a source of stress for Indigenous peoples (Cavanagh, 2020; Wooltorton et al., 2018). The Noongar authors consider the correct application of fire as integral to vegetation health. However, non-Indigenous land managers must recognise that it is not the responsibility of Indigenous peoples to remedy ‘unhealthy’ reserves brought about by agency mismanagement (Fache & Moizo, 2015), as highlighted by the Noongar authors in this study, for example: “We are trying to fix something here that is broken…We don’t have the knowledge about fixing” (Noongar Elder, 24 November 2020).

Noongar participants identified aspirations for governance and systematic inclusion throughout fire practice. This addresses the risks of appropriating Indigenous knowledge and people within western frameworks that are present in relevant literature from elsewhere (Nikolakis & Roberts, 2020; Petty et al., 2015). Hill et al. (2012) suggest that preservation and evolution of IFK can be achieved through maintaining Indigenous governance over burning. This aligns with Huffman’s (2013) definition of IFK as inclusive of “knowledge, practices and beliefs”; intrinsically highlighting an essential role of Indigenous people in IFK application to manage the Country.

**Knowledge**

The results of this research demonstrate extensive and nuanced IFK held by the Noongar Elders for the study area. The targeted application of fire to specific landscape features concurs with variations in Noongar disturbance patterns corresponding with landform variation in the SWAFR identified by Lullfitz et al. (2021). Ocbil theory demonstrates a need for targeted management sensitive to landform

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**Fig. 4** nMDS of all participants’ statement content based on a standardised measure of references to Huffman’s (2013) universal elements of IFK. Traditional Owners (Noongar participants) include seven Elders and one non-Elder. The community group members on the left of the plot belong to the same group, a different group to the community participant represented on the right. The fire practitioner shown at the centre-top of the plot is a private practitioner; all other practitioners work for the LGA. The ordination indicates a separation of participants by their position, but this is not a strong grouping. The stress of this nMDS is 0.19, a relatively weak representation. Due to the nature of the data (i.e., interview response), we consider it reasonable.
features in ancient and nutrient-poor landscapes worldwide and recognises the Indigenous knowledge that parallels this theory (Silveira et al., 2021). Our study found that granite outcrops hold high cultural value for Noongar people and are places where the application of fire is traditionally minimal. Congruence between Ocbil/Yodfel classification of landscapes and Noongar disturbance patterns, first highlighted by Lullfitz et al. (2021), shows the relevance of Indigenous knowledge in the contemporary management of threatened biodiversity in the SWAFR and potentially Ocbil-dominated regions worldwide. The small-scale nature of the reserves in our study prevented the examination of Noongar burning across large areas of land. However, it indicated that further research might provide greater insight into Noongar landscape alteration using fire at a larger scale, similar to that found by Prober et al. (2016) for the adjacent Ngadju Country.

The level of close attention to landscape features in Noongar IFK was not entirely captured by the distinctions between vegetation community types used in this study. This suggests precision burning for specific landscape elements by the Noongar people, such as for resource plant species, water, or specific cultural features. Precise and localised fire applications are typical of IFK systems globally (Nikolakis & Roberts, 2020; O’Gorman et al. 2022) and highlight the necessity of Indigenous knowledge holders in contemporary fire management. Critical attention to models of land management units, detailed cultural mapping, and the involvement of Indigenous peoples in fire planning on a case-by-case basis may facilitate better targeted and more sensitive fire management.

The most referenced Huffman’s 69 knowledge elements by Noongar participants align closely with five of Lullfitz’s et al. (2021) key themes for Noongar IFK of control, centrality to culture, location, patch size & spacing, and timing. Fire effects on vegetation, and other elements under the category Fire Effects (Appendix 1), show an intimate understanding of the outcomes of burning, demonstrating the predictive nature of Noongar IFK (Bowman, 1998; Huffman, 2013; Prober et al., 2016). Common elements grouped under Lullfitz’s et al. (2021) key theme of location demonstrate a careful and precise application of fire concerning specific landscape features to achieve desired outcomes. Focus on site preparation (Huffman, 2013) among Noongar study participants demonstrates that specific fire behaviour must be achieved to meet desired outcomes and that fire is applied more for its regenerative function than its ability to remove dead material.

The relevance of Huffman’s (2013) framework for developing an understanding of IFK to a Noongar context supports its universality. A loss of nuance can occur through appropriation and distillation of IFK in frameworks (Agrawal, 2002; Barbour & Schlesinger, 2012; Fache & Moizo, 2015) and so, knowledge elements used to explore data in the present research must be interpreted in the context of the knowledge system, including practices and beliefs, and with awareness that the framework presents a synthesised version of IFK (Huffman, 2013).

### Potential Application

Fire knowledge systems are tied to the ontologies that underpin them (Nikolakis & Roberts, 2020; Pyne, 2016). These distinct ontologies present a critical challenge and opportunity in collaboration between Indigenous and settler fire knowledge systems for fire management (Nikolakis & Roberts, 2020). The differing inherent understandings of fire between participant groups observed in this research, i.e., the intrinsic nature of fire to Noongar participants and the extrinsic positioning of fire by non-Noongar participants, are echoed across colonial contexts, where worldviews are informed by historical interactions with and cultural perceptions of fire (Nikolakis & Roberts, 2020; Thekaekara et al., 2017).

Recognising distinct ontologies in partnerships makes shared decision-making power necessary. Neale et al. (2019) suggest three critical elements for success in applying IFK: Indigenous control or decision-making power over land, building trust relations, and the commitment of crucial agency players to shift power imbalances. In a conceptual model, Nikolakis and Roberts (2020, Fig. 5) identify governance and the influence of power dynamics as a critical primary step in applying IFK. Our findings concur with the importance of governance and systematic involvement of Indigenous people at all stages.

Conversations in this study often fell into tropes identified by Neale et al. (2019) that application of IFK is positioned as either acting on the desires of Indigenous peoples, repressing Indigenous knowledge into settler frameworks, or as a simple expression of IFK, rather than the complex process that it represents. That discussion among non-Noongar participants was often speculative, demonstrates that IFK is present in thought but is primarily excluded from the application (Nyquist, 2019). By collaboratively investigating the similarities and differences in participant group approaches, we gained insight to rescind speculative discussion and inform a partnership based on mutual understanding.

The recognition by participants of the effort required to establish a successful partnership and re-introduce Noongar burning echoes Neale et al.’s (2019) categorisation of these attempts as “experiments.” Colonisation and exclusion of Noongar management have resulted in a new management context. Therefore, an ecological and social transition is required to facilitate a safe and mutually benefitting re-application of IFK. In places where Indigenous people have been systematically excluded from their traditional lands and
fire management, establishing governance may require institutional changes to management structures and land tenure (Neale et al., 2019).

This study used a framework of knowledge elements (Huffman, 2013) to interpret data. The loss of nuance in knowledge through this approach demonstrates its limitations. This loss suggests that the application of IFK when extracted from its context in broader Indigenous cultures, does not equate to the inclusion of that fire knowledge system (Eriksen & Hankins, 2014; Fache & Moizo, 2015). It is not the content of Indigenous knowledge that forms a partnership but a collaboration between peoples and agencies.

Conclusion

IFK is touted as a possible resource to improve current fire management practices, especially in the increasing risk and severity of wildfires. However, its reapplication is not straightforward in some contemporary contexts. We demonstrate that the IFK of the Noongar people in the SWAFR is nuanced, specific, fine-grained, and of substantial breadth. It is founded on land stewardship and inextricably linked to cultural and spiritual obligations. IFK may provide insights into more ecologically and culturally sensitive fire mitigation strategies but cannot be appropriated as the solution to agency mismanagement. Without its situated context in Indigenous paradigms, IFK loses nuance and is unlikely to meet its potential benefits.

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Data Availability The data supporting this research’s findings are available at the request of the authors. Data collected as part of interviews remain the intellectual property of those individuals interviewed.

Declarations

Ethics Approval This research was conducted under UWA Human Ethics Approval RA/4/20/6165. All participants gave free and informed consent to involvement.

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