Review

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Review

A Review of the State of Research on Cultural Burning and Threatened Species in Australia

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Abstract

Indigenous lands and land stewardship are increasingly recognized as crucial in terms of the persistence of threatened species, even in cases where Indigenous values with regard to species do not align with Western species concepts. Thus, knowledge about the interactions of Indigenous cultural burning practices and threated species would be crucial to conservation measures. Here, we review five case studies from Australia in order to better understand the effects of cultural burning on threatened species. What these reveal is a serious lack of research on cultural burning and threatened species. Such a paucity of knowledge must impact on the ability of fire practitioners to undertake cultural burning and the efforts of conservation agencies to protect threatened species. We recommend that institutions and government agencies partner in Indigenous-led research projects on the effects of cultural burning on threatened species to better understand the benefits that would accrue from cultural burning programs in terms of species protections and empowerment of Indigenous communities.

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Introduction

There is increasing awareness on the part of non-Indigenous people of the significant contribution of Indigenous knowledge and stewardship in terms of conserving the Earth's biodiversity and ecological systems. Lands that Indigenous peoples manage or have tenure over intersect with about 40 percent of protected terrestrial areas [1]. This is by no means a matter of coincidence, nor is it due only to the fact that due to colonization Indigenous peoples' occupation is largely of remote areas. Indigenous stewardship can consist of considerable human interventions at the landscape scale, while maintaining rich, biodiverse ecologies [1,2]. The ecologically sound nature of Indigenous stewardship in turn lends importance to Indigenous lands for the persistence of threatened species. Of 473 threatened mammal species examined by O'Bryan et. al., 47 percent occurred on Indigenous lands, and more than half of these had their habitat entirely on Indigenous lands [3]. This suggests that Indigenous lands hold critical habitat for these species and provides refugia for species with distributions that overlap with non-Indigenous lands. In Australia, three quarters of terrestrial and freshwater vertebrate species that are listed nationally as threatened have ranges that overlap with Indigenous lands, which in turn constitute 52 percent of the national estate [4]. According to Lilleyman et. al., Indigenous lands face 78 percent of the national threat load on imperiled bird taxa [5]. These data highlight the imperative to recognize the contribution to biodiversity and species protections provided by First Nations peoples and the weight of responsibility that they are burdened with. First Nations peoples and organizations should be given support for initiatives that empower them to undertake traditional custodianship of their lands because these contribute to threatened species protections [4].

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However, just because Indigenous managed lands maintain biodiversity and provide habitat for threatened species, it does not necessarily follow that these effects reflect an alignment of Indigenous and colonial values in relation to threatened species [6]. The Western concept of species is a construct based on a culturally mediated, value-laden, subjective set of parameters that in turn serve a culturally mediated set of values [7]. There is no objective basis for the Western species concept, rather it is emblematic of a colonial history of specimen taking, zoological gardens and disembedding of animals from their ecological entanglements [8]. In cases where an essentialist concept of species is mobilized to protect a particular population, this can in fact be inimical to Indigenous peoples' values. An example of this is where ecologists put forward a case for protecting particular populations of dingoes based on the concept of purity. The argument was that 'pure' dingoes were threatened by processes of hybridization with domestic dogs. This arcane conception of purity was heavily criticized in the Aboriginal statement on dingoes where Costello et. al. state: 'we know what it's like to be a dingo' [9]. This is a reference to racialization of Aboriginal people and judgements of not being 'black' enough that many Aboriginal people experience. In this case the concept of endangerment based on ideologies of purity is a form of racism that Aboriginal organizations cannot not be expected to endorse, and is likely another form of institutionalized trauma.

This is not to say that Indigenous peoples are never concerned about threatened species. Teagan Goolmeer has shown how Aboriginal species concepts are constantly evolving and can at times align with dominant colonial species paradigms, even where the underlying ontologies might be incongruent [10]. Species that are iconic in Western conservation paradigms may also be iconic for Indigenous communities, albeit depending on local factors such as clan associations. As such, there is often common ground on which concerns are shared. And underlying these perspectives on conservation of species is the possibility of extinction – a form of loss and disconnection that, over and above different cultural perspectives, is shared at a human level [6]. It is in these intersections of concern that productive conservation efforts might be realized because, despite differences in motivations or underlying values, the intent to create beneficial conditions for particular species are often in alignment. This can lead to partnerships that result in benefits for multiple stakeholders. It is also the case that Indigenous groups can benefit directly from colonial concerns for particular species. Where threatened species are present on Indigenous lands, this can be beneficial in obtaining funding and channeling resources towards ecological outcomes that are desired by both Indigenous and colonial stakeholders.

As such, there is a great amount of scope for research partnerships between Indigenous groups, research institutions, and government agencies based on the global concept of threatened species. This is particularly the case with cultural burning. As wildfire is a threatening process for many species, there is a great deal that stands to be gained by understanding how cultural burning affects species that are threatened. Considering that these species persisted and even thrived during tens of thousands of years of broad scale Indigenous fire management, there is likely a lot that can be learned from research that seeks to understand how threatened species respond to, benefit from, and contribute to cultural burning. Such research can provide benefits that include direction of resources towards cultural burning programs, capacity building for Indigenous ranger groups, access to Country and fulfilling cultural obligations toward land and species, protection of culturally significant entities, and increasing Indigenous involvement in fire management [6,11]. Here we review the state of research into cultural burning and threatened species using a series of case studies from Australia. This is by no means an exhaustive list and, while the prescriptions that follow are specific to Australia, these case studies might prove fruitful in generating impetus towards research partnerships in other countries. The species considered here were chosen due to their prominence as iconic species, their cultural associations with Aboriginal communities, their conservation status, and/or their close association with fire, whether positive or negative.

The statements on the significance of these animals to Aboriginal communities are not intended to be comprehensive, nor applicable to all Aboriginal communities and they do not speak for all

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Indigenous Australians. We also recognize that Indigenous Australians are custodians of their knowledge and stories of these species.

Koalas (Phascolarctos cinereus)

The conservation status of koalas in Australia is very much contingent. Prior to the Black Summer fires of 2019–2020, the conservation status of koalas was a matter of specifics [12,13]. While the northern population was listed as 'vulnerable', there were sub populations that were classified as endangered due to diminishing numbers and significant threats to these populations [14,15]. After the devastation of the Black Summer fires, the QLD and NSW populations of koalas were uplisted to 'endangered.' While these listings were based on trends in terms of numbers and on primarily anthropogenic threats, there is always a cultural underpinning to concern for koalas based on their iconic status, sentimentality towards them, and the ambassadorial roles that they hold in colonial Australia [16,17].

The importance of koalas to First Nations peoples reaches far beyond the colonial iconography. In First Nations lore, koalas embody ancestry and kinship as physical manifestations of ancient beings, ancestors, and progenitors of kin groups [6]. In story, their distinctive physiologies underpin the nature of the landscape and in some cases the very presence of people in particular places [18]. As such, the presence of koalas in the forest – their very bodies – connect people with ancient times and serve to reinforce stories of becoming and belonging. Moreover, the presence of koalas as food for particular groups enacts the life-giving nature of the forest as provider. These elements add much more to the imperative to preserve koalas in the landscape than the colonial desire to maintain an icon or protect a cute and cuddly animal.

Koalas are among the species in Australia that have a particularly high vulnerability to fire. As a slow- moving, arboreal species, koalas are particularly affected by fast moving crown fires [17]. In sufficiently dense forest they can jump from tree to tree, however not at such a speed that would enable them to escape a fire. For females carrying pouch or back young, their mobility is restricted even further [19]. Beyond the immediate threat of being burnt, koalas, as obligate folivores, are affected by crown fires in that their food source is destroyed. For males who have escaped flames this may not be as detrimental, as they are accustomed to being transient and indeed this strategy in a post-fire landscape can confer reproductive success [20]. However, for females who are highly philopatric and typically maintain small home ranges, the loss of their food supply due to wildfire entails relocating to another female's home range. This can result in excessive competition, over browsing, and high mortality rates [21]. These characteristics suggest that low intensity cultural burns, in reducing the probability of wildfires, and crown fires in particular, would be beneficial to koalas, especially females [22].

Considering the ostensibly ancient and enduring relationship that Australia's first people have with koalas, and the indications that low severity, patchy fires have little impact on koala populations, one would expect that cultural burning would not impact these animals negatively and in fact be beneficial. To date there is only one study that has directly addressed the effects of Cultural fire on koalas. This was a study undertaken by Samarawickrama on Minjerribah, North Stradbroke Island [19]. In this study the author sought to answer two research questions: 1. Did low intensity, cultural burns affect koala density on the island? 2. Did low intensity cultural burns have an effect on stress levels in koalas? Results from drone surveys demonstrated a decline in koala density across both controls and impact sites with the conclusion that cultural burning had no impact on koala density compared to the control. As for a relationship between cultural burning and stress levels, scat analyses demonstrated no significant impact of cultural burns on koala stress levels. As for the overall population decline, this was most likely explained as a consequence of seasonal factors. The study supported the accepted wisdom that cultural burning, in reducing the likelihood and severity of wildfire, and not negatively impacting koala density or stress levels, is beneficial to koalas.

Koala presence can be important in terms of securing funding and achieving land practice goals. By utilizing studies such as that by Samarawickrama, koala conservation concerns can be mobilized in ways that complement Aboriginal cultural imperatives to support conservation programs. For

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example, on Gumbaynggirr Country, where Koala aligns with sections and has a significant storyline, the Local Aboriginal Land Council secured funding for a koala monitoring program on land council land that is subject to cultural burning [18,23]. The demonstrated, continuing presence of a koala population on this land lends justification to the ongoing burning program and opens up access to funds based on the koala presence. In this way wider conservation concerns, koala iconicity, and Aboriginal land practices might align to achieve significant outcomes for Country.

Southern Brown Bandicoots (*Isoodon obesulus*)

Southern brown bandicoots were once widespread but their range has drastically declined. According to Paull et. al. their habitat was fragmented prior to colonization, likely due to their specialization in comparison to long-nosed bandicoots [24,25]. However, colonization amplified the fragmentation by an order of magnitude. Urban expansion, land clearing for agriculture, altered fire regimes, and climate change have severely impacted populations of southern brown bandicoots [24,26]. Where they do persist, they typically inhabit heathlands, riparian corridors, and swamp margins, all within 50kms of the coast [26]. This specialization limits the responses of southern brown bandicoots to external threats. Introduced predators and vehicle traffic also threaten these populations at the individual level, although their relationship to foxes appears complex. While Southwell et. al. found fox-proof fencing consistently appearing in optimal habitat models for southern brown bandicoots, Rees et. al. found no effect of fox controls on occupancy, suggesting a mesopredator effect by foxes on cats who would otherwise prey on bandicoots [27].

Regardless of their cryptic habits, various bandicoot species figure prominently in some Aboriginal origin stories. These stories are broadly distributed from southwest Western Australia to the east coast and from the central desert to Arnhem Land. Bandicoot figures as an ancestral being and progenitor, often in association with the origins of fire [28]. Stories often involve conflicting relationships between bandicoots and raptors, species that are notorious for stealing fire [18,29,30]. Bandicoot is also represented in a fire origin story from Arnhem Land that suggests a canny ability to survive wildfire [31]. These associations suggest fertile ground for exploring relationships between fire and southern brown bandicoots.

As ground nesting animals, bandicoots are normally only able to rely on burrows created by other animals, and so are especially vulnerable to wildfire [32]. At its most extreme, fire can cause local extinctions of bandicoot populations through incineration, habitat loss, and increased vulnerability to predators [33]. In a study across four sites in NSW, Wilson found that the only variable contributing to a gradient of population health for southern brown bandicoots was fire history [33]. In this case, the two sites of positive population health were only subject to controlled burns, while the others had been subject to wildfire. The effect of fire on habitat seems to be an important factor in population health. Catling et. al. found that habitat complexity rather than time since fire was the determining factor in bandicoot abundance [34]. However, these authors did not distinguish southern brown bandicoots from long-nosed bandicoots due to the similarity in their tracks. Meanwhile, Kirkpatrick et. al. found that time since fire was positively correlated with bandicoot visits and total diggings. This may have been due to increased predation by cats after fire due to the lack of cover [35]. Conversely, Rees et. al. found that southern brown bandicoot occurrence decreased with time since fire [27]. These confounding findings may be due to the differences in fires as variables, especially where studies do not provide details of fire intensity and extent.

To date there has been no research into the effects of cultural burning on southern brown bandicoots. There is, however, research on the effects of low intensity fire on this species. In a study of the southern brown bandicoot population at Ku-ring-gai Chase National Park, Hope monitored individuals before, during, and after a low intensity prescribed fire undertaken in May 2009. The extent of the fire was 24.6 hectares and the flame height 0.3 to 2 meters. The ignition pattern was open-ended, leaving opportunities for escape, the burn was patchy, leaving some places unburnt, and there was incomplete combustion of 30 percent of the leaf litter. A limitation of the study was that only one radio-tracked bandicoot was a southern brown bandicoot while the others were long-nosed bandicoots. The male southern brown bandicoot survived for at least 5 months post-fire.

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Another male southern brown bandicoot was captured adjacent to the burnt site in the post-fire period. Foraging frequency also increased for the southern brown bandicoots in the post-fire period, indicating a benefit from low intensity burns. Interestingly, during the burn one of the bandicoots fled the flames as far as the edge of his home range. At that point he doubled back on the flame front and sought shelter in a boulder pile. This suggests that site fidelity and home range size have a mediating effect on bandicoots' responses to fire, and highlights the importance of low intensity fire to bandicoot survival [36].

There is also scope for further research on the effects that bandicoots have on fire frequency, extent, and intensity. All bandicoot species are considered 'ecosystem engineers' [37], turning over tons of soil per year per individual. A study of southern brown bandicoot diggings averaged annual soil turnover in Yalgorup National Park at 45 foraging pits excavated per day, extrapolating to 3.9 tonnes of soil turnover per year per individual [38]. Bandicoot foraging pits have been shown to have significant effects on forest ecologies. The diggings increase soil conductivity and respiration, reduce hydrophobicity, and improve moisture retention. Foraging pits and spoil heaps promote fungal diversity, while spores are dispersed in bandicoot scats. These fungi make nutrients available to plants and increase plants' resistance to pathogens [39,40]. The pits trap and speed up breakdown of organic matter which promotes growth of micro invertebrates, bacteria, nematodes, protozoa, and actinomycetes [40]. The leaf litter breakdown in foraging pits also alters fire behavior. A study by Hayward et. al. found 37 percent reduction in leaf litter in sites occupied by bandicoots [41]. Fire behavior modelling predicted a 74 percent reduction in flame height and 33 percent reduction in rate of spread in areas where bandicoots were present [42]. These data suggest that research into cultural fire and bandicoots will reveal some key benefits not just to bandicoots but to broader forest ecologies.

Coastal Emus (Dromaius novaehollandiae)

Coastal emus walk a curious path in Australian conservation discourse. They constitute a local, almost completely isolated, population of mainland emus. The population is confined to a coastal strip of northern New South Wales, ranging from Evans Head in the north to Red Rock in the south. The estimated number of coastal emus at the time of writing is fewer than 50 birds [43]. Hence, they represent a critically endangered sub-group within a much larger population that, nationally, is listed as 'least concern' [44]. Coastal emus already occupy climatically sub-optimal habitat and they face a great number of primarily anthropogenic threats to their viability in the wild. These include loss of habitat due to expansion of agricultural land, increases in human population and expansion of peri-urban areas, predation by wild canids, loss of eggs to foxes and goannas, reduced range due to fencing and highway infrastructure, reduction in habitat due to climate change, habitat loss due to wildfires and harmful fire regimes, and genetic depression due to inbreeding [45,46]. As a consequence of these factors, coastal emus are at risk of extinction within the next 50 years.

Here, it is productive to understand the factors that lead to conservation concerns for coastal emus. After all, if they occupy sub-optimal habitat for emus, and that habitat is shrinking rapidly, why is it important to devote time and resources to preservation of this particular population? It is meaningful that rarity is cited as a cause for concern. However, in consideration of a thriving inland population, rarity alone would be insufficient as an underlying reason for conservation action. A contributing argument for the conservation of coastal emus is that they represent a genetically distinct subgroup. Davis et. al. demonstrated genetic divergence of coastal emus from inland emus based on thousands of highly resolving nuclear markers [45]. These authors argued, with some reservation, that this could be a basis for considering coastal emus as an 'Evolutionary Significant Unit', which in turn would designate them as a conservation priority. Another argument is that emus serve as vectors of seed dispersal, making the coastal population important for maintenance of biodiversity across coastal ecosystems [43,46]. Given the right conditions, emus can travel long distances – as many as 180kms in just 18 days - and the viability of seeds that survive in emu feces indicates a significant role for emus as seed dispersers for many plant species [47,48]. However, the effectiveness of emus as agents of seed dispersal are highly limited by human infrastructure such as

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fences and highways, which restrict emu mobility across the landscape, as well as the critically low population size.

While Western paradigmatic factors are mobilized to argue that resources should be dedicated to conservation of the coastal emu population, it significant that First Nations perspectives are also mobilized in conservation discourse and practice pertaining to the endangered population. In addition to arguing for seed dispersal and genetic difference as reasons for conserving coastal emus, the NSW Department of Environment and Heritage foregrounds coastal emus' cultural value among Bunjalung, Yaegl, and Gumbaynggirr peoples on the mid to north coast in its Saving our Species program [43]. Here the department partnered with Yaegl and Gumbaynggirr peoples to incorporate the significance of emus in story and songlines. Yaegl knowledge holder Shane Eamens explains how emus embody relationships across generations through stories that are manifest in the night sky. For Yaegl and many other peoples, the dark area of the Coalsack Nebula, just below the Southern Cross, is an emu that presents through the year as different times in his life cycle. These seasonal stories connect with the emus on the ground, presenting a cultural imperative to maintain these elements of a cultural-ecological whole. Among Gumbaynggirr people, the sky emu also connects emus with the cosmos. In a story originally told by Uncle Lambert Whaddy, emus' descent is traced to the upper Bellinger River and the Bellinger Valley, a place from which emus have recently disappeared [43]. Both the Yaegl and Gumbaynggirr stories are foregrounded in the Department of Environment's efforts to maintain populations of coastal emus on the mid to north coast. These have translated into significant resources being directed towards research, infrastructure and awareness programs dedicated to conservation of the coastal emu population. Meanwhile Goolmeer et. al. demonstrated the high level of cultural significance coastal emus have among Bunjalung people surveyed [49]. Respondents selected emus and six other species as high priorities for collaborative management approaches to conservation, including cultural burning programs.

At present, published research lags behind Indigenous knowledge on cultural fire and emus. Davis et. al. list 'inappropriate fire regimes' as a contributing factor to coastal emu declines, but no studies are cited and these authors do not include cultural burning in fire regimes [45]. Taking the extinction of Tasmanian emus as a correlate, it is possible that cessation of traditional burning practices was a factor in their disappearance [50]. Other studies have shown negative effects of fire on emus, but these were from hazard reduction burns and wildfire [51,52]. The only published study that we have found which describes emu relationships with cultural burning is ethnographic material from Western Arnhem Land. In their own language, Bininj Kunwok people discuss emus' relations with fire. These informants infer that cultural burning was not undertaken with 'emus in mind' and that benefits to emus were incidental. For example, when grevilleas were burnt to encourage kangaroos, emus increased in number as well. In fact, emus were averse to fire, as they would abandon nests in areas that were burnt, and leave for years from places that had experienced wildfire. However, the informants state that while emus avoid harm from fire, they always return to feed on the fruits and shoots that result from burning [53]. These data suggest that emus would benefit from cultural burning. One pressing question is whether patch mosaic burning would reduce the distances emus need to travel to find resources, as this in turn would reduce many other impacts on emu survival, such as motor vehicle strike. Hence there is a case for a more holistic approach to emu conservation in which a traditional approach to land management engenders positive outcomes for emu populations. At present Yaegl, Bunjalung, and Gumbaynggirr peoples are partnering with other organizations in efforts to protect emu populations, but these programs are in their early stages. Consequently, there is scope for the Aboriginal ranger groups on the north coast to undertake evaluation and monitoring of effects of cultural burns on emus, drawing on the resource pool that is available for coastal emu conservation. In these programs, the cultural significance of these birds can be connected to the ecological roles and the diminishing numbers that are a consequence of peoples having been forced from the land.

Ground Parrots (Pezoporus wallicus)

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There are two discreet populations of ground parrots: one in eastern Australia (*Pezoporus wallicus*), and one in south-west Western Australia (*P. wallicus flaviventris*). These ground-dwelling birds occupy coastal heathland habitats, feeding on seeds, nuts, flower buds, and other plant matter from a diverse range of heathland shrubs. They breed in late winter and spring, building hidden nests in low vegetation. The International Union for Conservation of Nature (IUCN) conservation status of ground parrots is 'least concern', however, under the *Biodiversity Conservation Act 2016* (NSW), the New South Wales sub-species is listed as 'vulnerable', and under the *Environment Protection and Biodiversity Conservation Act 1999* the western sub-species is 'critically endangered' [54,55]. This is due to habitat loss from wildfires, predation by cats and foxes, and competition with introduced species. There is currently a captive breeding program at Perth Zoo and re-introductions have been made at a national park east of Albany, Western Australia. At the time of writing the estimated population of *P. wallicus flaviventris* is 100–150 individuals, making it one of the rarest parrots in Australia.

Western ground parrots live on southern Noongar lands. These lands and peoples were heavily impacted by colonization from the 1840s onwards, and suffered significantly from killings, displacement, and introduced diseases [56]. This in turn led to severing of traditional fire regimes, which had a detrimental effect on the landscape, leading to increased frequency of wildfire and species extinctions. The Noongar name for ground parrots is Kyloring [57]. These birds are visually cryptic but aurally conspicuous in the early morning and late evening when their calls ring out. There are no published Noongar stories of ground parrots, which is not to say that the knowledge is lost. Renewed access to country presents opportunities for Aboriginal communities to revive stories [58]. The ground parrot's reliance on specific habitats, such as dense heathlands, aligns with areas traditionally managed and valued by Aboriginal peoples. This shared landscape fosters a connection that is both ecological and cultural, emphasizing the intertwined relationship between Indigenous communities and native bird species. Certainly, among Aboriginal peoples more broadly, birds figure prominently in stories as kin, as food, as indicators, and for decoration [59]. An example from central Australia of significance of the the night parrot gives some indication of how important a cryptic ground-dwelling parrot species can be [59,60].

Burbidge argues that it is not fire frequency per se that is threatening for ground parrots because ground parrot populations thrived under Aboriginal fire regimes [61]. Rather, it is the frequency, intensity, and scale of wildfires that occur within colonial Australian land use regimes that threatens ground parrots. Exactly the optimum fire frequency and intensity to which ground parrots are adapted is not yet established. Baker and Whelan surveyed numbers of eastern ground parrots after a wildfire at Barren Grounds Nature Reserve [62]. These authors found that numbers increased with time since fire over a period of 10 years. They suggested that vegetation density may have been more important than fire age in the provision of suitable habitat for ground parrots. Meredith et. al. argued that eastern ground parrots were 'fire-requiring' but not 'fire-adapted' birds [63]. This was based on findings that long-unburnt heath was too old to support ground parrots. However, Baker et. al. argued the converse, that ground parrots were fire-adapted but not fire-dependent [64]. These researchers found high densities of eastern ground parrots in sites ≥ 20 years post fire, which was consistent with other studies. These authors recommended that fire should not be used to manipulate the ecological functioning of ground parrot habitat. Burbidge's review of the studies up to that time found conflicting results. One study found the optimum habitat for ground parrots was at least 15 years unburnt, while another found highest numbers in sites 5–6 years post fire and 10–15 years post fire depending on habitat type [61]. However, these two studies were of the two different subspecies, western and eastern. In Burbidge's research at Fitzgerald River National Park, ground parrots moved into extensively burnt heathland only 6 years post fire [65].

Given that ground parrots are argued to be more vulnerable to fire than they are dependent upon it, it is worth exploring how they were able to persist through millennia of Aboriginal fire regimes. Ian Abbott addresses this very question regarding ground parrots and other avifauna of southwest Western Australia. In a systematic review of published and unpublished records from before and after settlement of the Denmark region in the 1820s, Abbot synthesized eye-witness

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accounts to produce a better understanding of how pre-colonial fire regimes complemented ground parrot populations [66]. Most significant in Abbot's findings is that fires were used even in hot, dry, and windy conditions at times of year conducive to wildfire. Abbot argues that parrots may have persisted in areas of 'totemic significance' that were protected by frequent low-intensity fires from late autumn to early spring. Records also indicate widespread patch burning at scales of 10 to 2000 hectares, which interrupted the spread of wildfire. Considering the key role of Noongar peoples in shaping plant communities in the area, it is unsurprising that it was after colonization that the ground parrot population was driven to the edge of extinction.

The historical evidence and the site-specific, nuanced nature of ground parrot relationships to fire-managed habitats suggest that there is scope for intersection of Noongar land programs and ground parrot conservation through cultural burning. The Noongar/Wudjari Native Title Settlement, the largest in Australia's history, presents an opportunity for collaboration in National Parks and Wildlife Services-funded programs that can directly and indirectly benefit ground parrots on Noongar lands [67]. This is especially the case where birds are being translocated – patch burning prior to translocation can provide not just protection against wildfire but also a series of successional stages of heathland vegetation could benefit introduced parrots. In fact, Burbidge et. al. recommend a mosaic of fire-ages and patch sizes for ground parrots [68].

Eastern Bristlebird (*Dasyornis brachypterus*)

With approximately 180 individuals remaining on Australia's east coast, eastern bristlebirds are listed as 'vulnerable' on the IUCN Red List of Threatened Species [69]. However, under Commonwealth and state legislation, their status is 'endangered' and/or 'critically endangered' [70]. Due to a host of threatening processes such as urbanization, land clearance, introduced predators, and altered fire regimes, the bristlebird population is highly fragmented. This fragmentation frames a separation between two groups: northern and southern. While these two groups have been proposed as separate sub-species, population-level genetic relatedness does not support this separation [71]. This relatedness between the two groups supports the contention that in pre-contact times there was a contiguous population of bristlebirds along the east coast that has been severely impacted by colonization. The northern and southern populations do utilize different habitats, with the northern population occupying open forest with dense tussocky grass, while the southern population occupies open heathland and open woodland with a heathy understory. Moreover, within these broader classifications there are local habitat preferences at particular sites [72]. Like ground parrots, bristlebirds are primarily terrestrial and so depend on understory vegetation for cover and nesting. Unlike ground parrots, they primarily eat invertebrates.

Eastern bristlebirds hold considerable cultural significance for Dharawal and Dhurga people from southern Botany Bay to Wreck Bay. The birds can be indicators of the approach of extreme weather and fire events. They also hold significance in that they nest in sedges and grasses from which people gathered seeds and fruits [73]. Meanwhile in southern Victoria, bristlebird is the totem (skin) of a local group and shares with the people a recent history of dispossession from the land by European colonizers [74].

Like ground parrots, bristlebirds are particularly fire sensitive and their vulnerability to inappropriate fire regimes is a key factor in their decline. As poor flyers who are dependent on cover, bristlebirds are unable to escape wildfire, unable to avoid predators after wildfire, and unable to quickly colonize areas that have been extensively burnt [75]. After wildfire, bristlebirds have been shown to move to already occupied, unburned habitats, without apparent resistance from resident bristlebirds over the short term, suggesting a tolerance for short-term overcrowding. At Barren Grounds Nature Reserve the absence of fire for 10 years also resulted in a population increase over the short term [76]. However, a few continuous years of no fire in Australian landscapes almost inevitably leads to wildfire, which can devastate bristlebird populations. Baker hypothesized that area of habitat burned is directly proportional to the reduction in population size. There are indications that time since fire is a significant factor in bristlebird occupation of sites [76]. This in turn differs for the northern and southern populations due to their different habitat requirements [77].

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However, in lieu of relocation efforts, there needs to be an extant population for recruitment to post-fire habitat to occur and this depends on local conditions and fire extent [78]. Pyke et. al. found that time since fire was not a significant factor when there were adjacent areas of unburnt habitat available [77].

The research on eastern bristlebirds' relationship with fire demonstrates a number of factors that suggest that bristlebirds would not be harmed by and likely would benefit from cultural burning. Foremost among these is that the patch mosaic nature of cultural burns leaves unburnt habitat available for bristlebirds to continue occupation, and from which they are able to recolonize burnt areas. This is supported by evidence that resident bristlebirds tolerate temporary occupation by others. Second is that the slow-moving nature of cultural burns and ignition patterns with a central ignition point and radiating fire front provide opportunities for bristlebirds to escape from fires. Third is that the low intensity of cultural burns fosters invertebrate inflorescences that provide bristlebirds with feeding opportunities. Considering the apparent compatibility of bristlebirds with cultural burning, there is obvious opportunity for research into the benefits of cultural burning for bristlebird populations.

The Commonwealth of Australia's 'Recovery Plan for Eastern Bristlebird' does acknowledge Traditional Owners' cultural associations with the bristlebird and makes recommendations for 'increased engagement of Traditional Owners in Eastern Bristlebird recovery decision-making processes.' This includes recognition that it is not just the birds that hold significant but the birds' ecologies and relationships to Country [79]. However, while the intentions are well meaning, these gestures are limited. There has been little engagement with Traditional Owners with respect to bristlebird conservation; most of the research work is undertaken by institutions without Indigenous guidance. This is despite the recommendations for mosaic, low-intensity burns and/or burns with small footprints with consideration for breeding seasons and environmental conditions. The performance criteria in the recovery plan do include Traditional Owners' involvement in decision making, incorporation of cultural values in conservation measures and identification of the significance of bristlebirds across their entire range. However, the recommended funding for this is less than 1 percent of the overall funding for the recovery project. Considering the fire prescriptions for bristlebird conservation, the stated intentions of the Commonwealth and the demonstrated cultural significance of bristlebirds, there is a strong case for Indigenous leadership in bristlebird recovery efforts, supported at state and Commonwealth levels.

Conclusions

There is a striking lack of research into interactions between cultural burning and the threatened species in the above case studies. The rare example of master degree research into koala stress responses and population density in relation to cultural burning highlights this. However, this reflects a paucity of research on cultural burning and animals in general. There are only two significant examples: that of Martu burning and monitor lizards in the Western Desert and Banbai Rangers burning and short-beaked echidnas (*kukra*) at Wattleridge Indigenous Protected Area in NSW [58,80]. Considering the marked increase in cultural burning programs, including burning at scale for carbon offsets, this needs to be addressed. The available evidence and research on non-Indigenous fire regimes suggest that cultural burning programs can provide significant net benefits for endangered species. However, risk-averse colonial institutions will be more inclined to support programs where there are demonstrated benefits. This will require some shifts in terms of the ontologies and traditions that underpin scientific research. Foremost is the need for 'walking together' for research on cultural burning to be Indigenous led with demonstrated benefits for communities and protections for intellectual property [81]. Second is the need to understand non-Western ways of categorizing species and conceptualizing endangerment and belonging [10]. It is not going to be acceptable for non-Indigenous researchers to bring Western frameworks and research protocols to understanding how Indigenous fire practices interact with animal ecologies and how these affect Indigenous cultural values. Third is that values in terms of Indigenous knowledge need

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to be adjusted to allow for greater levels of trust in Indigenous land management expertise. Overall, this research field holds much promise as there is considerable goodwill at the individual level and a willingness on the part of Indigenous organisations, government departments, funding bodies, and research institutions to produce knowledge of how cultural fire affects and is affected by threatened species.

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