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RESEARCH REPORT

Understanding Indigenous values and priorities for wetlands to guide weed management actions: Lessons from the Nardab floodplain in northern Australia's Kakadu National Park

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Summary Many wetlands around the world are vulnerable to invasive species and are also culturally important for Indigenous peoples. Yet, translating the complex values Indigenous peoples hold for wetlands into management actions to mitigate the impacts of invasive species can be difficult to put into practice. In this paper, we draw on an Indigenous-led project on the Nardab wetland in Kakadu National Park to show how understanding the local nuance of Indigenous values and priorities in different wetland places can guide more effective and inclusive weed management activities. At Nardab, Indigenous values and priorities guided the choice of three priority sites to manage the impacts of Para grass (*Urochloa mutica*) weed. Specific values and priorities were identified across the sites, including significant bush tucker populations, and harvesting sites, the ability for the site to support Indigenous knowledge sharing and ceremonial activities and the opportunity for visitors to enjoy a healthy wetland in this World Heritage Area. The values and priorities varied across the sites, so the actions needed to improve the health of these places were also place specific. The results showed that relationships between Indigenous people and places varied from site to site within a given wetland and could not be easily generalized when deciding on effective management activities. The paper highlights the benefits of supporting ecological, cultural and human-focused actions that Indigenous people wish to prioritize at selected sites to ensure the management of weed impacts on wetlands adequately reflect the diverse cultural landscapes that are embedded within Indigenous peoples' Country.

Key words: *Indigenous values, invasive species, weed management, wetlands.*

Ngaye nawu ngawokdi for kunredken ngardduk Ubirr. Kunkare birriwam birrimey ngalmangeyi, kedjebe, manimunak, djenj. Kunkareni. Kunkare birrikarrmi... njamed nakka Para grass. ... Manekke, bolkkime karrinan Para grass – wam. ... Bolkkime... birrimarnbom rowk now, kani manimunak, ngalmangeyi kabirriyawan, kabirrimang mayh kadberre, bonj. Kamak kabirrinan kabbal ngadberre, Wanjh kadjakdung, kabukmen karrimdurndeng, kabirrinan. Kamak rowk. Bolkkime namekke scientist mob birrimwam birridurrkmirri, birrimarnbom kamak rowk nawu ngadberre kunred. And bolkkime, mayh everywhere now. Namekke kabirridurrkmirri scientist, birrimarnbom kunred ngadberre kamak rowk. And bolkkime bonj. Karri rowk. Kabirrimang mayh. And might be next year kabirridurndeng yerrih kabirrimarnbun yerrih kabirrinan kamak rowk now.

I'm talking for my Country at Ubirr. In the past people used to hunt for long-necked turtle, file snakes, magpie geese, fish – that was back then. In the past there was... what's it, Para grass. ... Like today when we look for Para grass - [much of it has] gone. Now scientists [and rangers] have made it better again, so people can still look for magpie geese, and hunt animals. It's good if [we] check the floodplains. When it rains then later dries out, we all go back to check if the floodplains are healthy. And now there are animals everywhere. Those people have been working and looking after our Country to keep it healthy. And today, everything is there, and people still hunt for animals. And it might be that next year [we] will return and check if the land is still healthy.

Mr Na-gangila Bangalang, 30 Oct 2019

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Implications for managers

- Weeds such as Para grass (*Urochloa mutica*) can spread across wetlands and choke out valuable habitats, significant species and important sites that are important to local Indigenous communities.
- Indigenous-led weed management priorities for the Nardab wetland in Kakadu National Park show the need to consider the ecological (weed control); cultural (caring for sacred sites, protecting cultural and community heritage); and broader community (tourists enjoying a healthy wetland) values to guide effective co-management.
- Paying attention to the nuance of Indigenous values and priorities can inform the choice of where and what on-ground invasive species activities are to be implemented in different wetland management contexts.

Introduction

Caring for wetlands is a priority for Indigenous peoples around the world due to their connection to livelihoods, beliefs, rights and responsibilities (Neidjie 1989; Robb 2014; Ens *et al*. 2015). The management and rehabilitation of wetlands is also important for many countries due to their high conservation value and contributions to human well-being (MEA 2005). Invasive species are a growing threat to the health and integrity of many wetlands (Zedler & Kercher 2004), and this has prompted growing recognition of the need to consider Indigenous values and perspectives when understanding the impacts of weeds and feral animals (Robinson *et al*. 2005; Ens *et al*. 2016; Reo & Ogden 2018). In response to growing calls from Indigenous leaders around the world, agreements such as the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) have 'recogniz [ed] the adverse impacts of invasive alien species on biological diversity and its components, especially vulnerable ecosystems, such as wetlands... including those associated with Indigenous peoples and local communities' (CBD 2018 p.1) and recommend that 'when assessing the costs, benefits and prioritization of management of invasive alien species', governments and other organizations should 'explicitly include diverse social and cultural values of biodiversity across communities at the national level, including those of [I]ndigenous peoples and local communities' (CBD 2020 p.4).

Meeting the CBD's recommendations for invasive species management in wetlands requires enabling Indigenous peoples to define the impacts of invasive species on their values and priorities. Yet recommendations for wetland management remain largely based on ecological assessments and modelling (Melly *et al*. 2018), including advice on where to prioritize areas for invasive species management (e.g. Walden *et al*. 2012). While ecological science plays an important role in identifying measures needed to ensure healthy wetlands, effective management of wetlands that are significant to Indigenous peoples also needs to reflect Indigenous values. This requires understanding wetlands as bio-cultural systems that encompass Indigenous values, governance, and knowledge systems, with feedbacks between ecological states and human well-being (Bach & Larson 2017; Sterling *et al*. 2017). Effective management also requires recognition that wetlands contain specific places and kin-Country relationships that should not be generalized. Therefore, an understanding of local nuance across wetlands is necessary for effective care and management.

In this paper, we outline an Indigenous-led collaborative approach for selecting sites for invasive species management that reflected important Indigenous values and show how this was used to manage Para grass (*Urochloa mutica*) impacts at Nardab, a northern Australian wetland. This builds on a small but growing area of research that is finding ways to ensure Indigenous rights, priorities and values inform effective management strategies for conservation (Berkes 2004, papers in this issue). This research has confirmed that the impact of environmental changes on important place-kin relationships is complex and requires Indigenous-led approaches to direct wetland research and management, including activities related to invasive species impacts (Pyke *et al*. 2021). Yet cross-cultural conservation of wetlands and invasive species is challenging because dynamic and complex biophysical and socio-economic interdependences have been difficult for conservation managers to understand and translate into practice (Ens *et al*. 2016; Russell *et al*. 2020). As Robinson and Wallington (2012) have argued, the difficulty lies not in a lack of outcome measures – there are plenty of holistic measures of ecosystem health and ecosystems services (e.g. Sterling *et al*. 2017; Russell *et al*. 2020) – but rather in the underdevelopment of cross-cultural and collaborative *processes* that connect multiple values to agreed programmes of on-ground action.

Indigenous-led approaches to conservation have indicated that contributions of diverse knowledge and values held by Indigenous Traditional Owners can facilitate local ownership of on-ground decisions (e.g. Reo & Ogden 2018; CSIRO *et al*. 2019). Strategies that justify action based on ostensibly 'objective' science-based risk analyses alone have not been sufficient to motivate management in local settings (Cockburn *et al*. 2020). As a result, there is growing interest in finding improved ways for connecting Indigenous knowledge and values with on-ground management of invasive species impacts on wetland systems through collaborative processes. Collaborative processes based on respectful partnerships that empower local decision-making are increasingly presented as the best suited mechanisms to connect values and knowledge with action (Duncan *et al*. 2018, see papers in this special issue). Collaboration involves interactive and adaptive approaches to problem solving that weave different values and forms of knowledge in planning

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and management. Collaborative forms of knowledge co-production that respect Indigenous rights and responsibilities can also build trust and develop mutually agreeable solutions, and lead to improved bio-cultural landscape conditions and community well-being (Woodward *et al*. 2020).

Methods

Study site

Nardab is a floodplain in the East Alligator River region in northern Australia, which has always been owned and valued by local Indigenous groups, including its *Murrwan* and *Bunitj* Traditional Owners (hereafter '*Bininj*'). For details see Appendix 1. *Murrwan* and *Bunitj* people speak to Nardab in dialects of *Bininj Kunwok*, including *Kunwinjku* (Fig. 1). Nardab is also within the World Heritage-listed Kakadu National Park and has been listed as a Ramsar wetland of international significance and lies predominantly within Kakadu (Finlayson 2018).

Nardab floodplain management activities and partnerships between Traditional Owners and Kakadu National Park employees are guided by a joint management plan which is implemented under the direction of the Board of Management (Australian Government 2016). Through the Plan, there is commitment for *Bininj* Traditional Owners and Park staff to decide on: the most important values to recognize and protect; the most significant issues impacting those values; how those issues should be dealt with; and ways for *Bininj* people to be involved in the implementation of the plan (Australian Government 2016 p.i). An agreed outcome from joint management efforts to care for floodplain Country is to 'manage weeds on the floodplain, prioritising control of ecosystem-transforming weeds (including Para grass [. . .]) in priority areas' (Australian Government 2016, p.69). Indeed, the scale of the Para grass infestation on the Nardab floodplain means that Traditional Owners, and *Bininj* and non-Indigenous Park staff and rangers need to choose priority areas for on-ground management attention (Setterfield *et al*. 2013). For more details of the wetland and Kakadu National Park see Appendix 1.

Project design and governance

The research for this paper was undertaken during a 4-year Indigenous-led collaborative project that aimed to develop and apply local Indigenous indicators of healthy Country to direct and monitor the efficacy of on-ground management actions. The project was led by an Indigenous Research Steering Committee with Traditional Owner membership from all the clans in the Kakadu region. The Steering Committee chose Nardab as one of the priority areas to develop and test *Bininj/Mungguy* healthy Country indicators to guide adaptive and collaborative decision-making and action in Kakadu (for details see Robinson *et al*. 2021a).

The team was made up of Steering Committee members, Traditional Owners of each site, Indigenous co-researchers, district rangers and coordinators, Kakadu staff members, the Njanjma Rangers and a multi-disciplinary team of non-Indigenous research scientists. The project was funded by the National Environmental Science Program (NESP) Northern Australia Environmental Resources Hub, partnered with research institutions and received in-kind support from Kakadu through ranger and staff involvement. The project received human ethics clearance from CSIRO's Social Science Human Research Ethics Committee (reference number 050/18) and reciprocal clearance from Charles Darwin University's Human Research Ethics Committee (reference number H18055).

Site selection

For Nardab, senior Traditional Owners and the Steering Committee decided to focus on the impacts of Para grass (*Urochloa mutica*), a semi-aquatic weedy grass which has spread across *Murrwan* and *Bunitj* Country and poses a substantial and ongoing threat to the range of *Bininj* wetland values (Hunter *et al*. 2010; Bayliss *et al*. 2017). Previous research and *Bininj* assessments have described the impact weeds like Para grass have on water flow and habitat for significant bush tucker species such as magpie geese, due to its habit of spreading and choking out native grasses (Setterfield *et al*. 2013; Boyden *et al*. 2019). The need to choose high value areas to prioritize invasive species strategies has been recommended in previous studies, due to the high cost of removing all weeds from

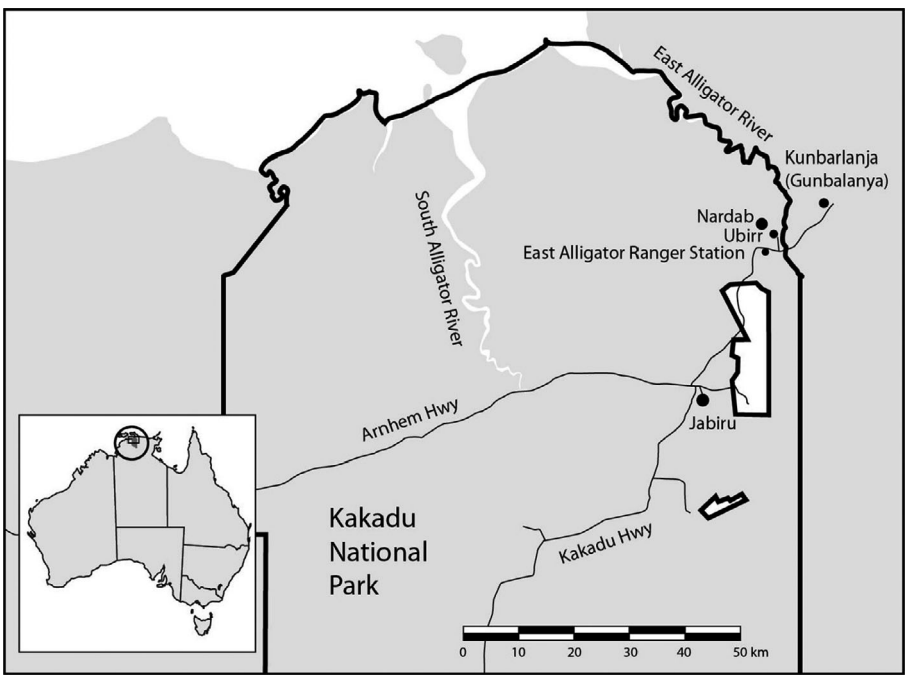


Figure 1. Location of the Nardab floodplain in Kakadu National Park

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all of Kakadu's floodplains (cf. McMaster *et al*. 2014). There has been some attempt to include Indigenous values in these assessments (e.g. Adams *et al*. 2018; Robinson & Wallington, 2012), but this is often reduced to a single value (e.g. harvesting sites) without consideration of the suite of values in a given place that might affect the choice of sites for management attention or the suite of actions needed to manage invasive species impacts at a given area.

In mid-2018 during the early stages of the project, senior Traditional Owners for Nardab worked with the team to select and agree on three priority sites to work at across the Nardab floodplain. The sites were chosen by Traditional Owners through a site selection process, which involved driving around the floodplain on two occasions in May and August 2018 and identifying sites where Traditional Owners wanted the team to focus their efforts (Fig. 2).

Traditional Owners worked with the research team, the East Alligator rangers and the Njanjma Rangers during a 3-hour workshop at the East Alligator Ranger Station in November 2018 to confirm key values and priority weed management activities at the three sites. At the workshop were two senior Traditional Owners (one male and one female), eight *Bininj* with family connections to Nardab (seven male and one female), one non-*Bininj* Indigenous ranger and three non-Indigenous Rangers (all male), and five research scientists (two male and three female). Other senior Traditional Owners with decision-making responsibilities for the floodplain who were not able to attend were consulted before and after the workshop to ensure their ideas and opinions were respected.

During the workshop, the sites were marked on a digital map and a hardcopy map, which was kept at the ranger station. Each site was approximately 1 ha to ensure it would be feasible for the team to manage and monitor Para grass at each place. During the workshop, the team agreed on the activities that could be undertaken to adaptively manage the impact of Para grass on the values at each of the three sites. The group also discussed and agreed on who would be responsible for implementing the actions, whether that be the district ranger team, Kakadu staff, Traditional Owners or the non-Indigenous researchers.

Elicitation of Indigenous values and priorities

From May 2018 to October 2020, members of the team conducted 27 site visits on 14 occasions across all the seasons. Sites were assessed before and after rangers sprayed Para grass at each site. Thirty-three *Bininj* Traditional Owners, Kakadu rangers and Njanjma rangers were resourced by the project to participate in site assessments over this period, and seven non-Indigenous Kakadu rangers, two non-Indigenous Njanjma rangers and five non-Indigenous research scientists were involved in various visits throughout the project (Appendix 2). During early site visits in 2018, sites were selected, values were articulated, interviews were undertaken and monitoring was commenced using drones, time lapse cameras and observations (for details see Robinson *et al*. 2021b).

In December 2018, nine *Bininj* and two non-Indigenous rangers and Kakadu staff undertook aerial spraying of the floodplain. The East Alligator Rangers then did follow-up ground spraying throughout 2019 and early 2020. In 2019 and early 2020, site visits included monitoring activities and interviews. Traditional Owners were consulted to give approval before every site visit and were employed to attend when available. Appendix 2 provides details on who visited which site when (including *Bininj* seasons), what activities were undertaken on each visit and who was interviewed.

During nine of the site visits in *Bininj* seasons *Wurrkeng* and *Kunumeleng* (2018), *Kudjewk*, *Wurrkeng* and *Kurrung* (2019, 2020), the two non-Indigenous research co-authors conducted semi-structured interviews with *Bininj* Traditional Owners and rangers to understand the impact of Para grass on *Bininj* values across the wetland and the effectiveness of the aerial and on-ground Para grass control. Ten *Bininj* Traditional Owners and rangers were interviewed, with five being interviewed on multiple occasions (for details see Appendix 2). Interviews ranged from 10 - 30 minutes and were undertaken opportunistically on the floodplain during site visits. Interviews were either conducted one-on-one or in small groups, depending on what people felt most comfortable with. Interviews were conducted using an Indigenous-led grounded theory approach (Chilsa 2012) to allow for flexibility. Interviews were predominantly in English, as per the preference of the interviewees, with one interview conducted in *Kunwinjku* and transcribed and translated by the *Bininj Kunwok* Language Centre. Informed consent was obtained before the interviews started as per ethics requirements and initials have been used for each interviewee to protect their identity.

Data analysis and communication of findings

Microsoft Excel was used to code and thematically analyse the interview data. A



Figure 2. Describing the values and priorities for managing site two (left) and site one (right) with Traditional Owner and Kakadu National Park Ranger Sean Nadji. Photo credits: Michael Douglas and Jennifer Macdonald

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description of the values, priorities and actions at each site was generated from the interviews. To ensure data accuracy, these descriptions were shared with senior Traditional Owners through project updates which were produced after every fieldtrip throughout the life of the project. The research team brought printed copies of the most recent updates to share and discuss on every fieldtrip.

Steering Committee members agreed to write journal papers, which would be co-authored by appropriate team members, as outputs for the project. The ideas in the present paper were discussed during an all-day meeting in Kakadu National Park in October 2020, at which three Traditional Owners for Nardab were present. A draft manuscript was prepared by the two non-Indigenous authors, which was shared and discussed with three senior Nardab Traditional Owners in March 2021. Traditional Owners suggested that they lead the co-authored paper, as we are telling a story about caring for *Bininj* values on *Murrwan* and *Bunitj* wetland Country. Sadly, in April 2021, the first author, Mr Na-gangila Bangalang, passed away. During a discussion about whether to proceed with publication, his family agreed that we should continue and that he should lead the publication as part of his legacy as a senior *Murrwan* Traditional Owner.

Results

In this section, we first describe the unique mix of interconnected and overlapping values and management priorities for Para grass that *Bininj* identified for each site. We then describe how these values and priorities were translated into the actions that were needed to mitigate against Para grass impacts on these priority areas.

Bininj values for the areas chosen as priorities for Para grass management

Through interviews and workshops with Traditional Owners and rangers, *Bininj* chose three sites to focus weed management attention for a mix of interconnected and overlapping values. These values reflect the responsibilities that *Murrwan* and *Bunitj* Traditional Owners have for their Country, and also reflect Traditional Owner and ranger priorities for the restoration of Nardab's wetlands, recognizing its position in a protected area of international significance. Below we summarize the key *Bininj* values described by interviewees for each site. For more details on the multiple values and weed management priorities at each of the three sites see Appendix 3.

Site one was used in the recent past by *Bininj* families for camping and hunting bush tucker, including magpie geese. As one Traditional Owner said, *'This is an important goose hunting area. When I was a child, the men would walk right out to the middle of the floodplain to hunt for goose.'* In the past, *Bininj* built platforms in the trees surrounding this area, from which they would '*get big mob of geese … when they were on the ground and when they were flying.'* Traditional Owners continue to spend time at this site as it is close to outstations where they now live, with one Traditional Owner driving out '*every one morning*' to '*have a look*'. Traditional Owners stated that they are not often successful in hunting efforts – '*currently getting bugger all geese and turtles'* – because the Para grass infestation makes it difficult for geese to nest or roost. *Bininj* have enduring family memories for this site, with one Traditional Owner reminiscing about the site as *'our favourite area, like for our hunting area, because I remember my grandad used to come up here and take us out.'*

Site two is a large area under the tourist lookout at Ubirr, which is visited by many national and international visitors every year. The site provides an opportunity for the rangers and Traditional Owners to show visitors a healthy wetland, with *'tourist*[s] *driving past, going up to the tourist camp.'* Traditional Owners and rangers *'want* [tourists] *to see the land still here, even the floodplain still here*.' While *Bininj 'used to do a lot of shooting'* here for magpie geese, in recent times *Bininj* stated that they do not hunt for magpie geese anymore because of the tourists; however, the large, open wetland area *'provides habitat and food for magpie geese and other native reptiles and fish'*. The area is also connected to *Ngalyod djang* (Rainbow Serpent dreaming), which means it is important for *Bininj* to visit the site to *'to learn about this story for them to keep [it] going … in their future for them and for their children. … Sometimes we have to bring them [children] and make them hear about the story*.' The site was identified by the rangers as an area to learn techniques for hand spraying Para grass because as one Traditional Owner and ranger stated, '*This would be a good spot for Bininj to learn to spray Para grass [because] it is an easy place to access and can be seen from the top of [the tourist lookout]*.'

Site three is located next to a high-traffic boat ramp frequented by tourists, tourism operators, Park rangers and staff and *Bininj* people. One ranger identified the site as *'important to look after' by 'remov*[ing] *the Para grass, because it's important for tourists to see that the rangers are doing a good job and looking after Country.'* It is an important long-necked turtle hunting site, used predominantly by *Bininj* women living at Kunbarlanja, with one Traditional Owner and ranger reminiscing about *'all those turtles* [the ladies] *caught'* after the rangers hand-sprayed the area during a management trip in 2018. Site three is connected to important *djang* (a sacred site), so according to cultural protocol regarding access and consent, it can only be visited when the right Traditional Owners are present (those with cultural authority) and is used as a learning place for *Bininj* children. A senior Traditional Owner described these protocols when he stated: '*That's [ok, as long as] you take a Traditional Owner … make sure they're going to ask us first [before] they go [on our lands]. Yes, because old people say that, we want to share [as a] family [with visitors]*.' As articulated by a Traditional Owner and ranger, '*There's a small amount of Para grass at this site and not many spots where it can enter through the waterways. Birds probably introduced the Para grass. We might be able to get rid of all the Para grass at this site*'. There

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was only about a quarter of a hectare of Para grass at the site with limited entry points through the waterways, so the East Alligator rangers were confident they could rid the site of all Para grass.

Synthesis of site values

Site one was chosen predominantly for its importance to senior *Bininj* Traditional Owners, including for the *Bininj* family and bush tucker values. The vicinity of the site to outstations where *Bininj* Traditional Owners live ensured they could continue their practices of caring for and monitoring Country by direct observation and close, continual, lived experience. While Traditional Owners expressed hope that the Para grass management would improve hunting opportunities for culturally important magpie geese, of equal importance was having the right people and their families spending time together at this place, on Country, sharing traditional stories and creating new ones. Site one is predominantly visited by Traditional Owners, who control access to the site with a locked gate.

In comparison, sites two and three were chosen by *Bininj* to protect a range of values that reflect the importance of this joint-managed protected area not only for the *Bininj* owners but also for tourists and rangers. The location of site two below a significant tourist lookout gave the rangers an opportunity to showcase their management efforts to tourists and other visitors. Similarly, site three provided *Bininj* and non-Indigenous rangers and staff with an opportunity to show tourists and other visitors the success of their cooperative efforts to manage invasive weeds and care for Country. This is significant as many Kakadu rangers have worked for decades managing the escalating threat of invasive weeds (Hunter *et al*. 2010). Additionally, while site three is not used to hunt for magpie geese due to its proximity to the boat ramp site, it is used by senior *Bininj* women to hunt for long-necked turtles. The choice of this site by male Traditional Owners and rangers shows their knowledge and appreciation of gendered practices of hunting and caring for Country.

Connecting multiple *Bininj* values at each site to the on-ground actions needed to care for Nardab as wetland Country

The *Bininj*-led effort to articulate the multiple values at each site was supported by Kakadu National Park rangers and guided the choice of actions that was recorded by the research team and determined as critical to care for these places within this significant biocultural landscape. The differing values and priorities at each site chosen by *Bininj* meant that they identified nuanced management actions (Fig. 3).

At sites one and two, aerial spraying (with a helicopter) was identified by the Kakadu rangers and staff as the preferred management strategy and was later conducted with assistance from the Njanjma rangers and an external helicopter pilot to remove large areas of Para grass infestations and restore magpie goose habitat. At site one, Traditional Owners noted the increase in the number of geese on the floodplain a month after spraying had been completed. However, they also noted the ongoing lack of access due to a strip of Para grass the helicopter missed which made it impossible to walk onto the floodplain to hunt for geese. Follow-up ground spraying by Kakadu rangers was therefore conducted to improve Traditional Owner access to the site. The openness of site two meant it was used as a training area for Kakadu rangers to learn how to undertake on-ground Para grass spraying so that it was environmentally and culturally safe. Site three was small and surrounded by Melaleuca (paperbark) woodlands, and so the Kakadu rangers used quad bikes to navigate to access and spray the Para grass patches.

In addition to the weed control actions undertaken to control Para grass, *Bininj* led other management activities to care for each site. After site one had started to rehabilitate after Para grass control, senior Traditional Owners from the nearby outstation spent time visiting the area with their families, checking on Country and sharing stories of old people (Elders and ancestors) hunting. At site two, there was an emphasis on ensuring *Bininj* and non-Indigenous rangers were working side-by-side under the guidance of Traditional Owners to learn to undertake culturally and ecologically safe weed management activities. At site three, monitoring and management trips were organized for when senior *Bininj* women were able to attend, so they could care for Country and culture by hunting for long-necked turtle before the rangers hand sprayed the Para grass. The turtles were then taken back to Kunbarlanja and shared appropriately with kin.

Discussion

Recognizing and applying Indigenous values to invasive species management decisions is essential to for inclusive conservation that protects ecosystems and safeguards Indigenous Peoples' rights and futures (Reo & Ogden 2018; Pyke *et al*. 2021). Wetlands are increasingly impacted by invasive species and are also places of significance for Indigenous peoples and conservation (Robinson *et al*. 2005; Hunter *et al*. 2010). This has prompted a growing area of research to understand Indigenous values of wetland species and habitats (Reo & Ogden 2018; Russell *et al*. 2020) and perspectives of invasive species and impacts (Ens *et al*. 2016; Bach & Larson 2017).

This paper builds on the growing body of cross-cultural ecology and Indigenous-led conservation that has developed frameworks and methods to understand how Indigenous values and priorities can be incorporated into invasive species impact assessments and collaborative management efforts (Bayliss *et al*. 2017; Adams *et al*. 2018). This paper shows that the cultural and physical geography of wetlands influences Indigenous priorities for invasive species management, which varied from place to place across the wetland.

This project offers lessons for research scientists and land managers who work with Indigenous peoples to manage invasive species in significant ecosystems. The diversity in environmental management and restoration choices reflects the multiple human perspectives about what

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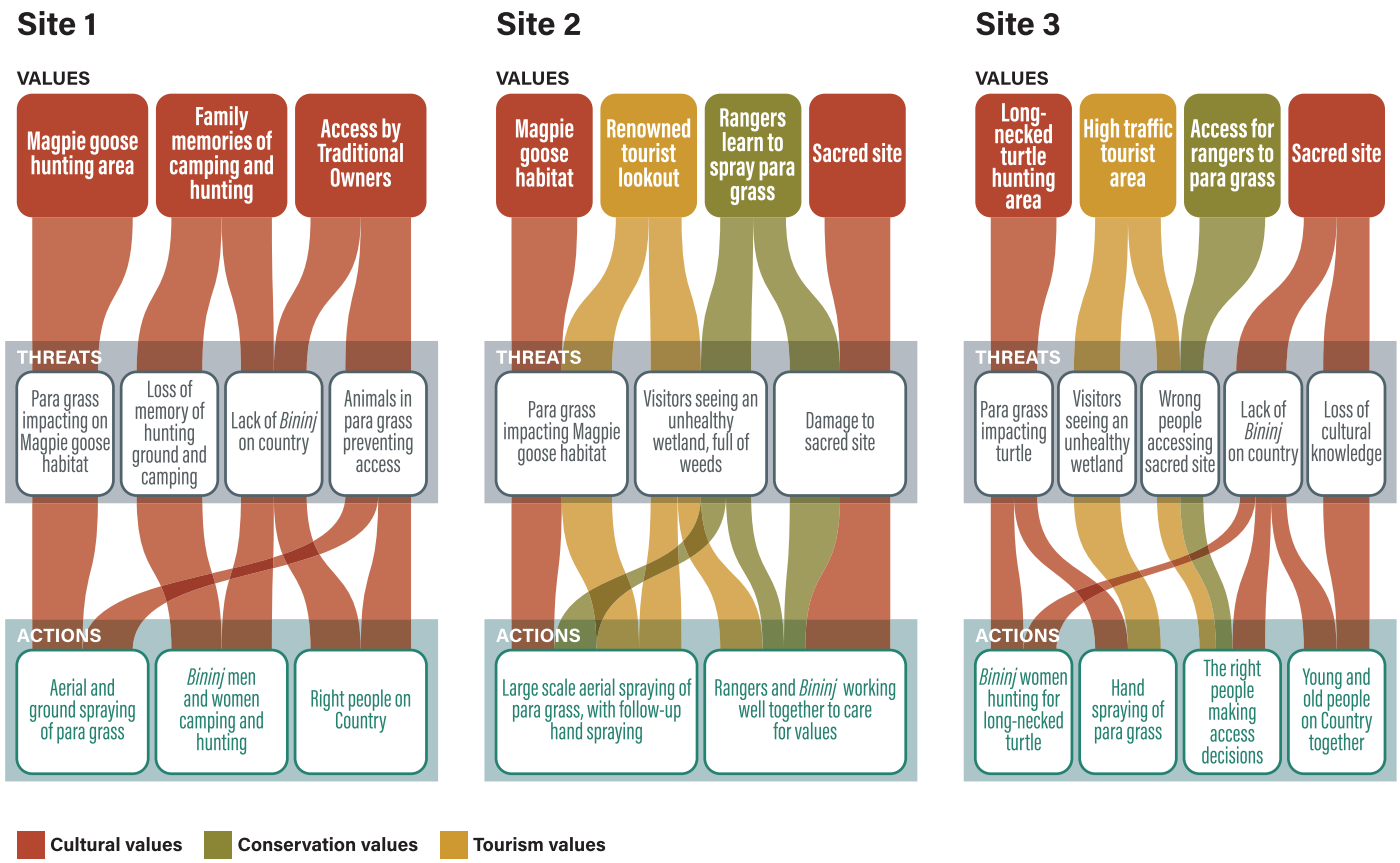


Figure 3. Understanding the multiple values at each site led to site-specific actions needed to manage the impact of para grass in priority places connected to Nardab's holistic wetland system

is deemed 'valuable' and a priority for management investment (Strang 2005; Pullin *et al.* 2013). Wetlands contain significant species and places where Indigenous cultural and community heritage is shared and remade. Many wetlands, such as Nardab in Kakadu National Park, also reflect histories of post-colonial relations and interactions that continue to affect relationships between local Indigenous people, sacred sites and living resources.

Drawing on our project in Kakadu National Park, we have shown how Indigenous wetland values and priorities were used to identify sites to focus weed management attention. *Bininj* priorities for weed management differed between sites depending on the level of weed infestation, cultural values, tourist visitation and proximity to where *Bininj* and their families lived. Hence, *Bininj* values and priorities had local nuance across the Nardab floodplain. Effective weed management was not just about the removal of Para grass from the three sites. The actions needed to reduce weed impacts on these wetlands were motivated by ecological (Para grass removal), cultural (caring for sacred sites, facilitating access to Country for hunting and intergenerational knowledge transfer) and economic (enabling tourists to enjoy a healthy wetland) aspirations. These wetlands and weed management actions were driven by kin-Country responsibilities and relationships that are unique to *Bininj* and Nardab, although they resonate with similar motivations for caring for Country commonly described by Indigenous peoples elsewhere (Austin *et al.* 2019; Russell *et al.* 2020). *Bininj* priorities for weed management also recognize that the wetland is Ramsar listed and part of a World Heritage National Park, and Kakadu rangers and Traditional Owners work together to ensure that the cultural and natural heritage values of the National Park are protected and maintained.

Further research to identify socio-ecological and economic stresses across whole wetland systems at Nardab would be useful, including how these stresses affect Indigenous assessments of the efficacy of weed management activities. While the present research focussed on understanding *Bininj* values and priorities to guide management actions to mitigate the impacts of Para grass, a better understanding of how the interacting effects of other environmental pressures such as climate change, fire, human activity and feral animals on local Indigenous wetland values would be beneficial. This could guide more holistic and connected management strategies in different places and help to understand how place-based management strategies can connect to care for the entire wetland. The Kakadu National Park plan recognizes that to keep wetlands healthy, all partners, working together with adequate investment, need to share responsibility for identifying the multiple

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values, threats and possible solutions to guide effective and long-term restoration of ecosystems (Australian Government 2016).

Conclusion

Local Indigenous cultural-ecological geographies bind individuals, clans and Country together (Neidjie 1989). Indigenous peoples around the world recognize that local dialogue and collaboration offer a way to reconcile multiple values through actions that reflect and respect Indigenous peoples' rights and relationships with the wetland and priorities for its care (Oviedo & Ali 2018). Collaborative partnerships between Indigenous peoples and conservation agencies have shifted conservation paradigms and practices to include Indigenous rights and cultural dimensions (Bach & Larson 2017; Austin *et al*. 2019). Although there is a range of international and national policy instruments, standards and targets that acknowledge Indigenous people's values and knowledge as a key platform for managing biodiversity and ecosystems, translation of these commitments into conservation priorities and practice remains inconsistent (Hunter *et al*. 2010; Pyke *et al*. 2021). There is a critical need to ensure Indigenous-led and holistic approaches drive conservation activities to empower Indigenous values and rights, and the knowledge and practices in the places that sustain them.

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Appendix 1

Nardab wetlands in Kakadu National Park

Bininj Traditional Owners and local Indigenous residents regularly visit the Nadab wetlands and surrounding floodplain including for ceremonies, to practice wetland burning and to hunt for bush tucker species like ngalmangeyi (long-necked turtle, Chelodina rugosa), kedjebe (file snakes, Acrochordus arafurae), manimunak (magpie geese, Anseranus semipalmata), and djenj (fish spp.). Magpie geese use the floodplain to breed, build nests, lay eggs and raise their young. The food that people hunt on the floodplain is prepared, cooked and shared according to rules given to Bininj by the Old People. Hunting and gathering practices are guided by six kunmalk (seasons) at Nardab: Kudjewk (monsoon, around January to March), Bangkerreng (late wet season, around April to May), Yekke (cooler weather, around June), Wurrkeng (cold weather, around July to August), Kurrung (hot and dry, around September to October), and Kunumeleng (humid, build-up, around November to December) (Yibarbuk and Cooke 2001; Narndal *et al*. 2015). Adding to its significance as a living, bio-cultural landscape, Nardab is connected to ngalyod, the Rainbow Serpent, and other sacred sites and stories, which are re-enacted and passed on to Bininj children. Today, most Traditional Owners live close to the floodplain at nearby outstations, at the East Alligator Ranger Station, and at Kunbarlanja (Gunbalanya), a community on the Arnhem Land side of the East Alligator River.

Nardab is in the East Alligator district and is co-managed by the Kakadu National Park East Alligator District Rangers and local Traditional Owners. Nardab is also part of the wetlands and floodplains that have been listed as a Ramsar wetland of international significance and which lie predominantly within Kakadu National Park. The Njanjma Rangers, based at Kunbarlanja, are also involved in the management of Nardab, as some of the Njanjma Rangers and their senior Traditional Owners have rights and management responsibilities for Nardab.

Nardab floodplain management activities and partnerships between Traditional Owners and Kakadu National Park employees are guided by a joint management plan which is implemented under the direction of the Board of Management (Australian Government 2016). The board has 15 members, 10 of whom are Traditional Owners representing the clans in the region, and the chair of the board is appointed from among Indigenous members. This Board was established in 1977 as part of a series of agreements that incorporated Nardab into a bigger area to create the joint management, World Heritage-listed Kakadu National Park, which is

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leased to the Australian Government based on legal frameworks set in place by Australia's Environmental Protection and Biodiversity Conservation Act 1999 (Cth) and the Aboriginal Land Rights (Northern Territory) Act 1976 (Cth) (Lea *et al*. 2018). Through the Plan, there is commitment for Bininj Traditional Owners and Park staff to decide on: the most important values to recognise and protect; the most significant issues impacting those values; how those issues should be dealt with; and ways for Bininj people to be involved in the implementation of the plan (Australian Government 2016 p.i).

Appendix 2

Nardab site visits, 2018-2020

Date	Season	Sites Visited	Who attended	Activities
22/05/2018	Bangkerreng	2	1 Bininj and 1 non-Indigenous ranger, 5 researchers	Site selection
16/08/2018	Wurrkeng	1,3	2 Bininj rangers, 2 researchers	Site selection, interviews
4/12/2018	Kunumeleng	1,2,3	8 Bininj and 3 non-Indigenous rangers, 2 researchers	Site assessment (drone, time lapse cameras)
5/12/2018	Kunumeleng	1,2	2 Bininj and 1 non-Indigenous rangers, 2 researchers	Site assessment (drone, time lapse cameras, ground assessments, interviews)
7/12/2018	Kunumeleng	1,2	9 Bininj and 2 non-Indigenous rangers, 2 researchers	Spraying, Site assessment (interviews)
21/03/2019	Kudjewk	1,2,3	4 Bininj rangers, 1 researcher	Site assessment (interviews)
3/04/2019	Bangkerreng	1,2,3	4 Bininj rangers, 3 researchers	Site assessment (drone, ground assessments)
27/06/2019	Yekke	2	2 Bininj and 3 non-Indigenous rangers, 2 researchers	Site assessment (ground assessments)
13/08/2019	Wurrkeng	1,2,3	9 Bininj and 4 non-Indigenous rangers, 5 researchers	Site assessment (drone, ground assessments, interviews)
16/09/2019	Kurrung	1	8 Bininj and 2 non-Indigenous rangers, 2 researchers	Site assessment (drone, ground assessments)
28/10/2019	Kurrung	2,3	7 Bininj and 1 non-Indigenous ranger, 5 researchers	Site assessment (drone, ground assessments, interviews)
29/10/2019	Kurrung	1	2 Bininj and 1 non-Indigenous ranger, 5 researchers	Site assessment (drone, ground assessments, interviews)
30/10/2019	Kurrung	2	3 Bininj and 1 non-Indigenous ranger, 5 researchers	Site assessment (drone, ground assessments, interviews)
28/10/2020	Kurrung	2,3	13 Bininj and 2 non-Indigenous rangers, 2 researchers	Monitoring (drone, ground assessments)

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Appendix 3

The multiple values at each of the three sites on the Nardab floodplain chosen to focus management of Para grass impacts

Site	Site value	Details of site value to *Bininj*	Example/s
One	Hunting	Magpie goose hunting ground	*'This is an important goose hunting area. When I was a child, the men would walk right out to the middle of the floodplain to hunt for goose. My Aunties would come and hunt for turtles. As a child, we would get big mob of geese here and we could hunt for geese when they were on the ground and when they were flying. We're currently getting bugger all geese and turtles [because of the para grass].' SN 16/08/18*
	Family memories	Memories of hunting magpie geese & camping with family members	*'This used to be a hunting ground for a lot of our families, like from Oenpelli and that. Even long-necked turtle, that's another thing that getting affected [by para grass], long-necked turtle, file snakes, that live in there. . . . These are the things that I haven't eaten since I was 16, 17, when I was going to school. We used to walk from here to Border Store to get food, fishing as well but mainly walking, that used to be our track through there. Now you can't walk through there, it's just overgrown.' JN 13/08/19* *'This is our favourite area, like for our hunting area, because I remember my grandad used to come up here and take us out. I just want this place to come back clean so everyone can come back hunting.' JD 13/08/19*
	Access	Access by Traditional Owners	*'Every morning I drive to the front there and have a look. A lot of goose coming in hey, and landing. And in the evenings, you can see them flying back here. So, they're moving around now. And that didn't happen a few years ago.' JN 13/08/19*
Two	Hunting	Magpie goose habitat	*'Like magpie geese, in the wet season, like this time, when it starts raining, we need magpie geese to come over [because] in the wet season [beginning in] March, they start to make new nests, you know, fix [them] up more. [Later] that's when [they lay] the goose eggs, [so later] by that time she's going to make more, you know, more little ones now [make] nests [so she can] breed, so we're going to have more magpie geese on the floodplains.' NB 30/10/19* *'This site provides habitat and food for magpie geese and other native reptiles and fish. . . . We used to do a lot of shooting but there's a lot of people over there [gestures at the tourist lookout].' JN 13/08/19*
	Tourism	Internationally significant tourism destination, providing an opportunity to show tourists a healthy wetland	*'We want this one to stay open because we got the tourist driving past, going up to the tourist camp. We just want everyone to see the land still here, even the floodplain still here.' JD 13/08/19*
	Access	Access for rangers to learn to spray para grass	*'This would be a good spot for Bininj to learn to spray para grass. It is an easy place to access and can be seen from the top of [the tourist lookout].' SN 16/08/18* *'Kakadu - they done a good job for us, Parks Australia, involving us, Aboriginal people and Traditional Owners, to join [with] us, to help us see [how] our Country [could] look like. . . . In Kunwinjku I will say, "kamak rowk". It means that I will thank you mob, people, . . . [for] supporting us, helping us to do the job [of looking after Country] with us. And [for] showing us, so in the future we can do [it] ourselves.' NB 30/10/19*
	Sacred site	Ngalyod djang (Rainbow Serpent sacred site)	*'This area's got little bit of stories about Rainbow Serpent. . . . It's important for them [Bininj] to learn about this story [djang] for them to keep going to the, in their future for them and for their children. . . . Sometimes we have to bring them [children] and make them hear about the story.' JD 13/08/19*
Three	Hunting	Long-necked turtle hunting area	*'When they did the spraying last year, some ladies caught turtles before they sprayed. You should've been there to see all those turtles they caught.' SN 21/03/19*
	Tourism	High-traffic tourist area next to boat ramp, providing an opportunity to show tourists a healthy wetland	*'It is still important to look after this area and remove the para grass because it's important for tourists to see that the rangers are doing a good job and looking after Country.' FH 16/08/18*
	Access	Access for rangers to all para grass infestations	*'There's a small amount of para grass at this site and not many spots where it [para grass] can enter through the waterways. Birds probably introduced the para grass. We might be able to get rid of all the para grass at this site.' SN 16/08/18*

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Appendix 3. (Continued)

Site	Site value	Details of site value to *Bininj*	Example/s
	Sacred site	Djakarna djang (Jabiru sacred site)	*'That's [ok, as long as] you take a Traditional Owner . . . Long time ago old people used to share - we're still family. But make sure they're going to ask us first [before] they go [on our lands]. Yes, because old people say that, we want to share [as a] family [with visitors].' NB 30/10/1*

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